Ecosystem Sciences Division Standard Operating Procedures: Data Collection for Rapid Ecological Assessment Benthic Surveys

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Introduction

This document is intended as a reference and provides guidelines for training, sampling, and data entry for the monitoring of coral populations and benthic communities as part of the Pacific Reef Assessment and Monitoring Program (Pacific RAMP) led by the Ecosystem Sciences Division (ESD) of the NOAA Pacific Islands Fisheries Science Center (PIFSC). The standard operating procedures (SOP) outlined in this report apply to the Pacific RAMP surveys that ESD and its partners conduct in the coral reef ecosystems of ~ 40 primary islands, atolls, and shallow banks in the Hawaiian Archipelago (including Papahānaumokuākea Marine National Monument), the Mariana Archipelago (Guam and the Commonwealth of the Northern Mariana Islands, including the Marianas Trench Marine National Monument), American Samoa, and the Pacific Remote Island Areas Marine National Monument (Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands). As part of ESD's ecosystem assessment and long term monitoring efforts, coral colonies and the benthic community functional groups are surveyed at Rapid Ecological Assessment (REA) sites selected using a stratified random sampling design. The details of the methods employed are outlined here.

Objectives

The objective of this document is to establish guidelines and procedures for implementation of sampling design, survey methodology, and data entry for the monitoring of reef coral populations and benthic communities as part of the Pacific RAMP led by ESD.

The two primary objectives of the monitoring effort are to: 1) determine status, trends, and variability of coral populations and 2) determine status, trends, and variability in benthic reef coral communities. Coral population metrics including abundance (density, proportion occurrence, totals), size structure, partial mortality, prevalence of coral condition such as disease and bleaching and generic and species richness are generated along with community metrics such as relative abundance (percent cover), frequency of occurrence, and coral community taxonomic composition. Monitoring occurs within each of five regions [main Hawaii Islands (MHI), Northwest Hawaiian Islands (NWHI), American Samoa (SAMOA), Pacific Remote Island Areas (PRIA), and Guam and the Commonwealth of the Northern Mariana Islands (MARIAN)] in the Pacific at islands within regions and among strata.

Methodology

Description

Sampling Design

While there are several methods to select a sample from a population, a selection method can be devised that provides more accurate and precise survey estimates if information is known about a population. In situations where there is either very little information about the metrics to be collected or there is no spatial structure in the variance of these metrics, a simple random sampling design is appropriate. However, coral abundance metrics are typically heterogeneous and vary in space according to certain environmental covariates such as depth, topographic complexity, and patchiness of reef habitats (Smith et al. 2011; Swanson, 2011). Given the general knowledge of heterogeneous distributions of coral populations, benthic maps of environmental covariates can be used to effectively divide the sampled area into strata. Random samples can be allocated into these strata based on each stratum's proportional area and the variance structure of the population within the stratum. This type of stratified random sampling design (StRS) is capable of more effectively and efficiently sampling a coral population than a simple random sampling design (Cochran 1977).

The StRS design requires that surveys at each site are both efficient and high quality. Efficiency increases the ability to survey more sites, which improves the power of population, island and stratum-specific (spatial) estimates of abundance, density, size structure, partial mortality and prevalence of disease and bleaching. The improved quality of data at each site translates to more accurate estimates of abundance, size structure, and condition, as well as interpretation of the spatial pattern of these estimates.

In general, the stratification scheme for these surveys incorporates geographic sub regions of islands, reef zone components (such as back reef, lagoon, and fore reef), and depth (0–30 m). Ultimately, reef habitat types that reflect a gradient of complexity and patchiness will be incorporated into the stratification scheme as the resolution of benthic maps improves for each region. A two-stage stratified random sampling (StRS) design is employed to survey the coral reef ecosystems through the U.S. Pacific regions. The survey domain encompasses the majority of the mapped area of reef and hard bottom habitats from 0 to 30 m depth. The stratification scheme includes island, reef zone, and depth in all regions, as well as habitat structure type in the main Hawaiian Islands. The habitat structure types include simple, complex, and coral-rich. Depth categories include shallow (0–6 m), mid-depth (> 6–18 m) and deep (> 18–30 m; due to bottom time limitations, 25 m is generally the cutoff depth). Allocation of sampling effort has been proportional to strata area since 2013; however, the variance structure of target coral taxa (optimal allocation of samples among strata according to both stratum size and variance) will be incorporated as of 2018. Sites are randomly selected within each stratum.

A geographic information system (GIS) and digital spatial databases of benthic habitats, reef zones, bathymetry, and marine reserve boundaries are used to facilitate spatial delineation of the sampling survey domain, strata, and transects. Map resolution is such that the survey domain can be overlain by a grid using a GIS with individual cells of size 50 m × 50 m in area. A two-stage sampling scheme following Cochran (1977) is employed to control for spatial variation in population parameters at scales smaller than the grid cell minimum mapping unit (2500 m^2). Grid cells containing hard-bottom reef habitats are designated as primary sample units (referred to as sites), while the second-stage sample unit are defined as a diver visual belt transect of fixed area (10 m^2 or less; Smith et al. 2011).

Benthic survey components

Surveys at each site are conducted along two 18-m belt transects (Figure 1) and include the following suite of observations:

1) Adult coral colony (≥ 5 cm) abundance, size, partial mortality and condition
2) Crustose coralline and Alcyonarian disease
3) Anthozoan presence
4) Juvenile coral colony (< 5 cm) abundance and size (3 m^2)
5) Benthic cover

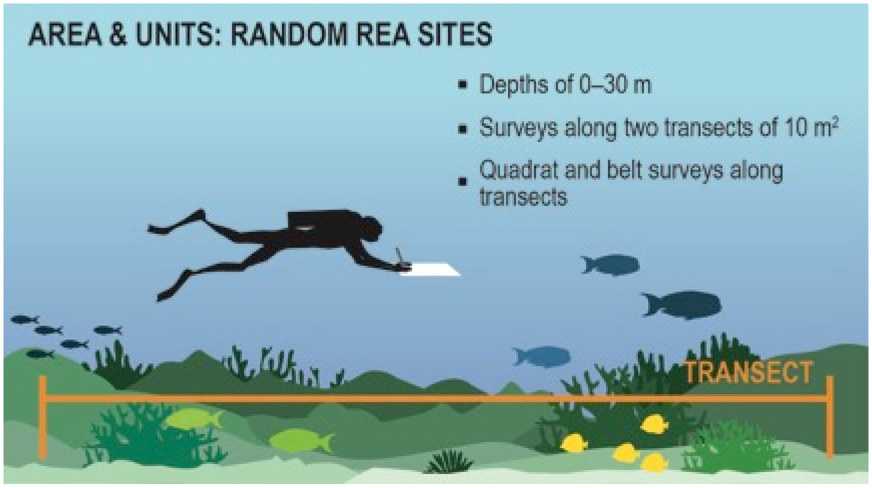


Figure 1. Diagram of a diver conducting a belt survey at an REA site.

Adult coral colonies

Adult coral colonies (≥ 5 cm, max. diameter) are surveyed within four (1.0 × 2.5 m) segments at 5-m increments along the 18-m transect in the following manner: 0−2.5 m (segment 0); 5.0−7.5m (segment 5); 10−12.5 m (segment 10); and 15−17.5 m (segment 15). The combined survey areas of the segments is 10 m^2 per transect and 20 m^2 per site. All colonies whose center falls within 0.5 m on either side of each transect line are identified to lowest taxonomic level possible (species or genus), measured for size (maximum diameter to nearest cm), and morphology is noted. In addition, partial mortality and condition of each colony are assessed. Partial mortality is estimated as percent of the colony in terms of old dead and recent dead. The cause of recent mortality is identified when evident. The condition of each colony including disease (not attributed to recent tissue loss) and bleaching is also noted along with the extent (percent of colony affected) and level of severity (range from moderate to acute). The lowest taxonomic level is species in the main Hawaiian Islands and the Northwestern Hawaiian Islands. For the remaining three Pacific regions, the lowest taxonomic level of coral identification is genus, except for a select number of species that can be consistently identified to species by all divers conducting the surveys. The number of species may change for each survey year depending on the experience and training of the benthic divers conducting the surveys. For example, a total of 77 coral taxa were identified to the species level during the 2015 RAMP surveys in American Samoa and the Pacific Remote Island Areas.

Crustose coralline algae (CCA) disease and Alcyonarian disease

Within the same four segments per transect as the adult coral surveys, both crustose coralline algae (CCA) diseases and Alcyonarian disease are surveyed. Within each segment, disease occurrence and lesion size (max. diameter) are noted.

Anthozoan (other cnidarians) presence

In addition to the adult coral surveys, CCA diseases, and Alcyonarian disease, the presence of other Anthozoans (other cnidarians including Alcyonareans, Zoantharians, corallimorphs, and Antipatharians) are also noted.

Juvenile coral colonies

Juvenile coral colonies (< 5 cm, max diameter) are surveyed within three (1.0 × 1.0 m) segments along the same two transects: 0−1.0 m (segment 0); 5.0−6.0 m (segment 5); and 10.0−11.0 m (segment 10). The combined survey area of the segments is 3 m^2 per transect and 6 m^2 per site. Juvenile colonies are distinguished in the field by a distinct tissue and skeletal boundary (not a fragment of larger colony). The size of each juvenile colony is measured by recording both the maximum and perpendicular diameter to the nearest two mm. Similar to adult corals, juvenile corals in the MHI and NWHI are identified to species if possible. In the remaining three Pacific regions (MARIAN, PRIA, and SAMOA), juvenile corals are identified to genus with the exception of a select list of species that are identifiable *in situ*. However, in some cases, juvenile corals will generally be too small to identify to species no matter what region is being surveyed.

Benthic cover

Estimates of benthic cover are derived from benthic images (hereafter photoquadrats) which are photographed along two 18-m transects. Benthic substrate photos are collected at 1-m intervals on each transect for a total of 15 photoquadrats per transect and 30 per site. The benthic photoquadrat imagery is analyzed by using the web-based annotation tool CoralNet (Beijbom et al. 2015). CoralNet assigns 10 random points per photo and the benthic elements falling directly underneath each point are identified to three functional group levels: Tier 1 (e.g., hard coral, soft coral, macroalgae, turf algae, etc.), Tier 2 (hard coral by morphology: massive, branching, foliose, encrusting, etc.), and Tier 3 (e.g., hard coral by genus and morphology; macroalgae by genus and grouped genera). The standard operating procedures for the analysis of benthic substrate imagery can be accessed at Lozada-Misa et al. (2017).

Field Implementation

Equipment

Survey dives are conducted from small (6–9 m) boats, launched from the support ship or shore-based launch ramp, to the pre-selected, random stratified dive sites. Prior to launching each morning, equipment should be packed and transported onto each small boat (Table 1).

Table 1. Gear required for diving operations.

Topside	Per Buddy Pair	Per Individual Diver
Global position system (GPS) unit loaded with pre-selected, random stratified sites	Two 30-m transect tapes	Benthic survey data sheet on underwater slate
REA site list	Surface marker buoy with 50-m dive reel	Region specific field “cheat sheet” for coral taxonomic identification
REA site map		Pencils
Dive and navigation information datasheet		Ruler or rulers (large 40-cm ruler for adult coral size measurements, small 15-cm ruler for juvenile coral size measurements)
Randomized list of depths per depth strata		0.5-m stick (PVC stick marked at 5-cm intervals)
		1-m monopod (PVC collapsible stick for photoquadrat surveys)
		Underwater digital camera for taking benthic photos and/or taking photographs of any unknown coral species to be identified later

Site Selection and Assessment

Prior to the start of each mission, random survey locations (REA sites) are generated and field survey maps are created. For each day of field operations, the benthic team lead will use these materials to provide a list of primary and alternate sites and relevant maps for each dive team. Alternate sites serve as backup sites in the event that primary sites turn out to be unsuitable (e.g., because of mapping errors in depth or substrate type) or inaccessible. Before departing for dive operations, the waypoints for REA sites at the island or atoll to be surveyed are uploaded into the benthic team GPS units. Waypoints are randomly placed within a REA site, and are named with a site ID (a standard 3-letter island code and a 3 or 4 number site code).

Upon arrival at the REA site, record the depth of the random point (using the small boat depth sounder) and make sure that divers descend to that depth to avoid biasing where along the depth contour transects are placed. Divers should inspect the site by snorkeling; **the area to be surveyed must contain a minimum of 25% hard-bottom habitat**. Therefore, surveys should not normally be conducted in sand habitats. However, where substrate is hard bottom with a light but consistent cover of sand, it is still acceptable to survey in that habitat. If the random site location is too deep for the target stratum, the divers should swim perpendicular to the contour of the reef towards a shallower location. If we do need to adjust our site due to an inappropriate depth then we should refer to a list of random depths for each depth bin rather than choosing our own depth. Topside, the new site coordinates should be recorded on the GPS unit while noting the original coordinates and the depth. If the benthic habitat is sand, sediment, or does not contain a minimum of 25% hard-bottom habitat, the divers should swim in one direction for 1 minute to try to find suitable habitat (Figure 2) within the depth range of target stratum. If no suitable reef habitat is found, the site should be aborted and the team should relocate to the next site or alternate site. Divers should not swim toward a site that “looks” good (e.g. more coral). The GPS coordinate for the unsuitable site (e.g., Figure 3) should be recorded on the Dive and Navigation Information Sheet (Figure 50) and listed as unsurveyable, either as sand, *Halimeda* flat, too deep, or other.

Although the divers will attempt to conduct the survey at the exact locations of the random waypoints for a site, the actual location of the survey may shift due to unsuitable habitat at that position, or due to the boat or divers being inadvertently displaced due to conditions such as strong current. Therefore, it is critical to record the actual location of the survey using the handheld GPS unit. Divers should work with small boat coxswain to determine either a signal (such as setting the surface buoy once an appropriate site is reached) or strategy to record the site waypoints while the divers are conducting the survey. The GPS coordinate for the site location should be recorded on the Dive and Navigation Information Sheet (Figure 50).

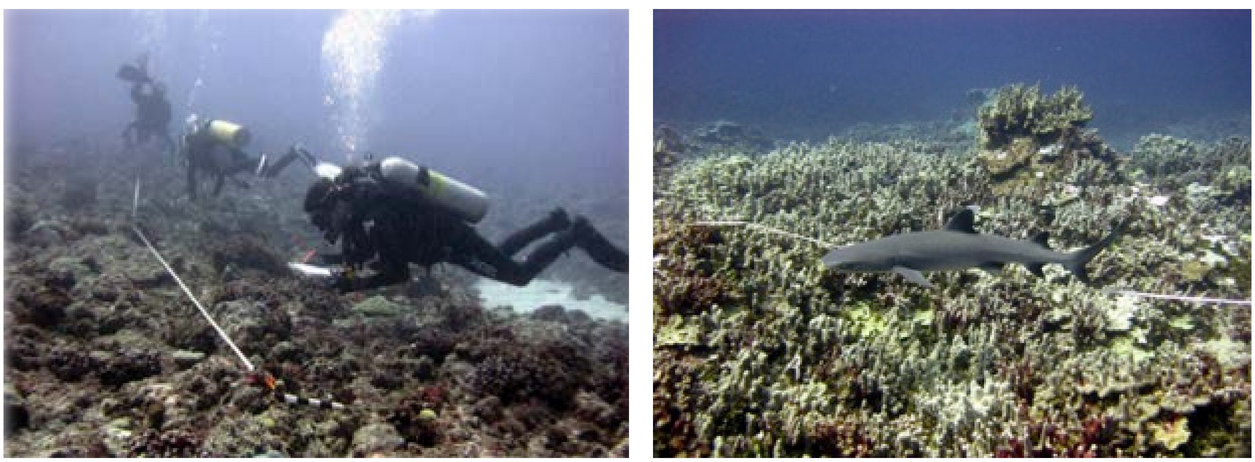


Figure 2. Examples of suitable habitat. ***NOAA photos***

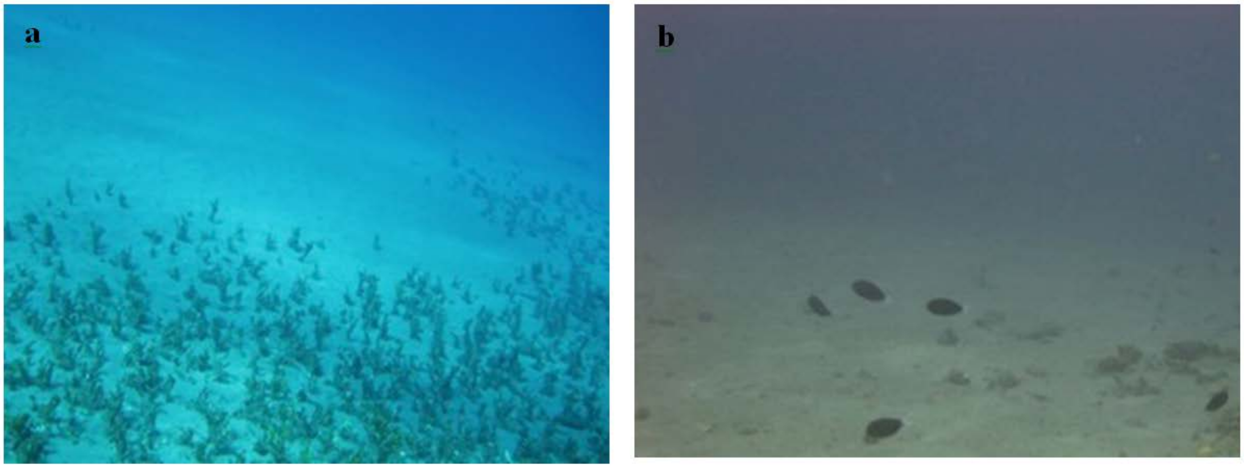


Figure 3. Examples of unsuitable habitat: (a) *Halimeda* flat, (b) sand. ***NOAA photos***

List of tasks

At each site, the following tasks should be completed by the dive team:

1) Deployment of transects
2) Site characterization
3) Record minimum and maximum depths for each transect area (recorded in feet)
4) General site photographs
5) Signal boat for proper GPS coordinate location with surface float
6) Ecological surveys: Adult corals, CCA and Alcyonarian disease, Alcyonarian presence, and Juvenile corals
7) Photoquadrats for benthic cover estimates

The separation of tasks among the dive team may vary but all members should work cooperatively to survey each site as efficiently and safely as possible.

Deployment of transects

If the survey area encompasses a steep incline (~ > 45°), then the two 18-m transect lines should be deployed along the depth contour; otherwise, the transect lines should be run from offshore to inshore. The transect lines can be relatively parallel, but should be separated by at least 3 m (Figure 4). If the transects are deployed to follow a depth contour, they should be separated by at least 3 m as well (not end-to-end). Each transect should be well secured to the bottom to avoid transect movement.

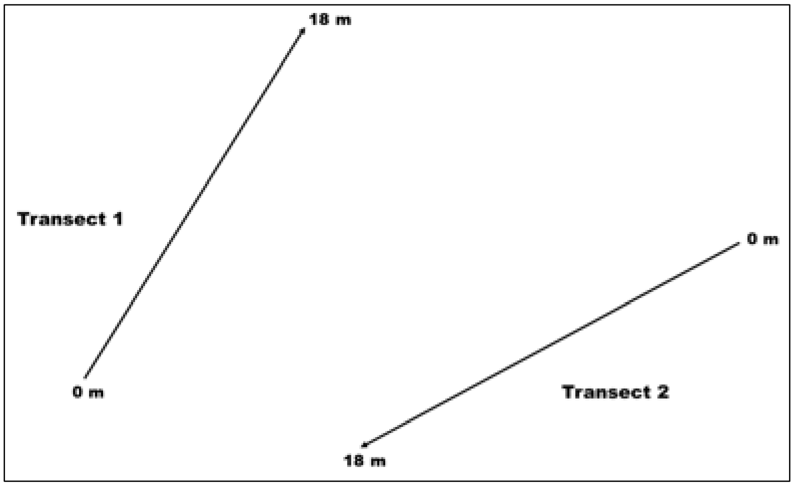


Figure 4. Diagram of transect deployment.

Recording site and survey data

Benthic survey and site characterization data are recorded underwater on the benthic survey data sheet (Figure 5) At the top of the data sheet, there are specific sections to record the diver names or initials (**A**), the date (**B**), the island and habitat types (**C**), site notes (**D**), site name (**E**), the minimum and maximum depth (in ft; depths will be converted to meters in database) around transect 1 (**F**) and transect 2 (**G**). There is additional space for comments at the bottom of the data sheet (**H**).

Figure 5. Sample benthic survey data sheet used underwater to record coral colony survey and site characterization data.

Site characterization

Site photos

The primary photographer should take a minimum of four landscape-oriented photos of the site (Figure 6). These photos should be taken from within the general transect area (e.g. between the two transects) and are generally taken at evenly spaced intervals as the diver rotates 360°. More photos or video may be taken as needed to provide a permanent record of the overall characteristics or unique features of the site.

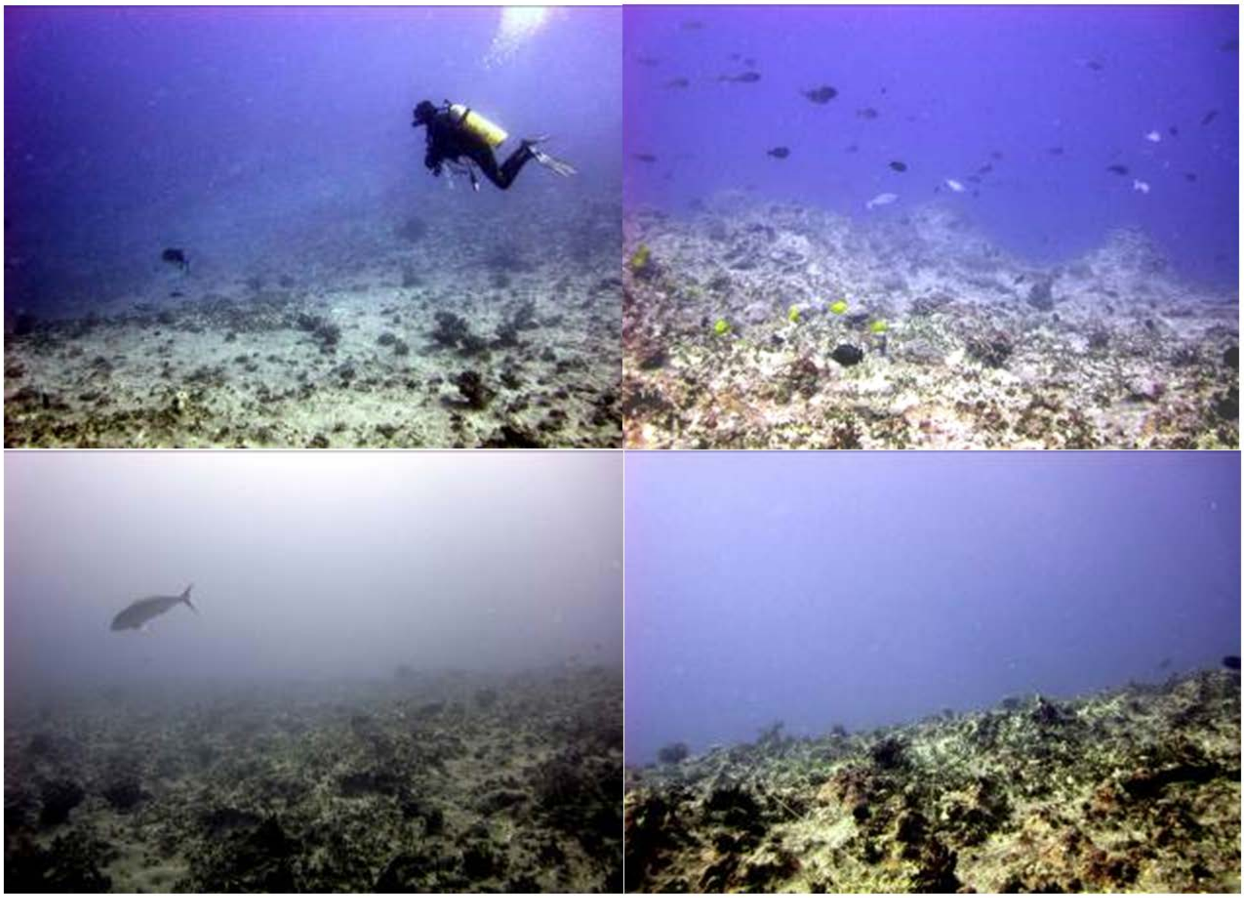


Figure 6. Examples of site photos taken within a transect area. ***NOAA photos***

Habitat types

Reef habitat type should provide a description of the general survey area (50 × 50 m grid cell, 2500 m^2). This is characterized by selecting the most appropriate choice that describes the habitat encompassed by the general survey area from the following ten categories that have been modified from Kendall and Poti (2011):

1. <u>Aggregate reef (AGR):</u> Hard-bottom substrate with corals; also referred to as continuous or consolidated reef (Figure 7). This habitat type may have high relief but lacks the sand or pavement channels of spur and groove habitat. Most reefs that do not obviously fall in other types should be recorded as aggregate reef.

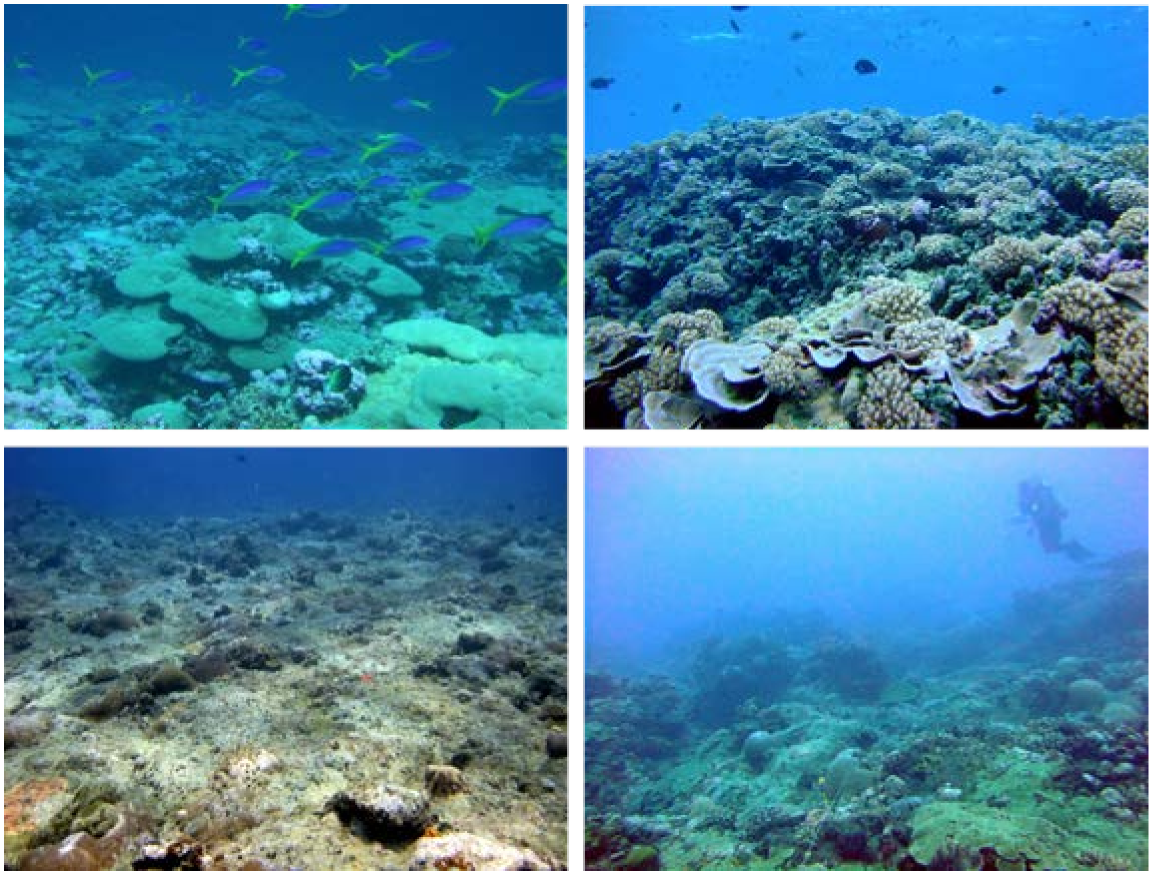


Figure 7. Examples of aggregate reef. ***NOAA photos***

2. Aggregate patch reef (APR): Coral formations that are isolated from other coral reef formations by sand or other habitats and that have no organized structural axis relative to the shore or shelf edge (Figure 8). They are often characterized by a circular or oblong shape with vertical relief of 1 m or more in relation to the surrounding seafloor. Reefs in this category are larger or equal in size to the general survey area of 50 × 50 m. This habitat type is most commonly found in lagoon (e.g. Rose Atoll) or back reef areas (e.g. in northern Pearl and Hermes Atoll and Midway Atoll).

Figure 8. Aerial imagery of an aggregate patch reef in Kāne‘ohe Bay, O‘ahu, Hawai‘i. ***Photo by J. Levy, University of Hawai‘i Applied Research Laboratory***

3. Aggregate patch reefs (APS): This category is for patch reefs that have the same defining characteristics of an Aggregate (Individual) Patch Reef, but are smaller in size. Therefore, multiple patch reefs are found within the 50 × 50 m survey area (Figure 9).

Figure 9. Examples of aggregate patch reefs habitat. ***NOAA photos***

4. Pavement (PAV): Flat, low-relief, solid rock in broad areas often with partial coverage of sand, algae, hard coral, gorgonians, zoanthids, or other sessile invertebrates that are dense enough to begin to obscure the underlying surface (Figure 10).

Figure 10. Example of pavement habitat. ***Photo by D. White, Hawai`i Department of Land and Natural Resources***

5. Pavement with patch reefs (PPR): Areas of pavement with occasional patch reef formations that make up less than 10% of the general area (Figure 11).

Figure 11. Examples of pavement with patch reefs habitat. ***NOAA photos***

6. <u>Pavement with sand channels (PSC):</u> Habitats of pavement with alternating sand/surge channel formations that are perpendicular to the shore, bank, or shelf (Figure 12). The channels of this feature have low vertical relief relative to spur and groove formations and are typically erosional in origin. This habitat type occurs in areas exposed to moderate wave surge such as the bank/shelf zone.

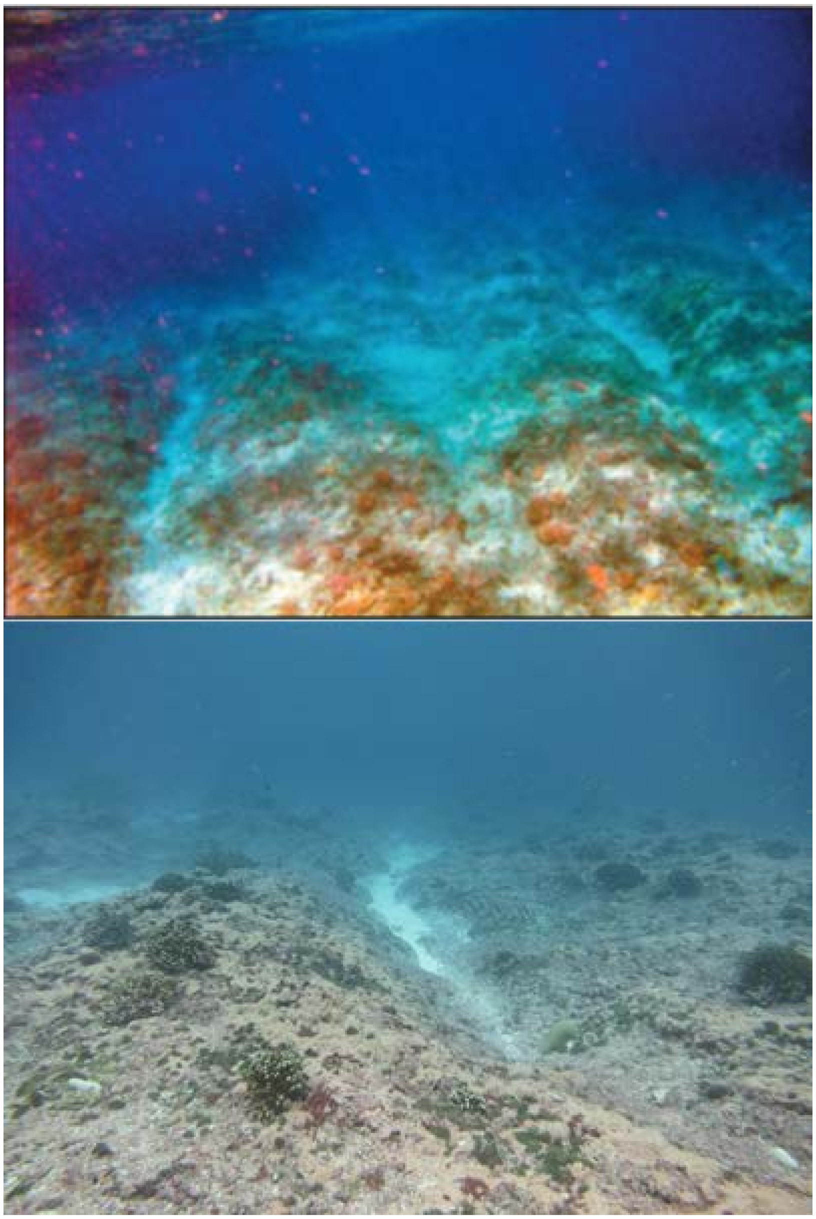


Figure 12. Examples of pavement with sand channels habitat. ***NOAA photos***

7. Rock/Boulder (ROB): Large, irregularly shaped carbonate blocks or boulders or volcanic rock, often extending offshore from the island bedrock or headlands. This habitat type can also occur as aggregations of loose rock fragments that have been detached and transported from their native beds. Individual boulders generally range in diameter from 0.25 to 3 m, with variable levels of benthic cover present (Figure 13).

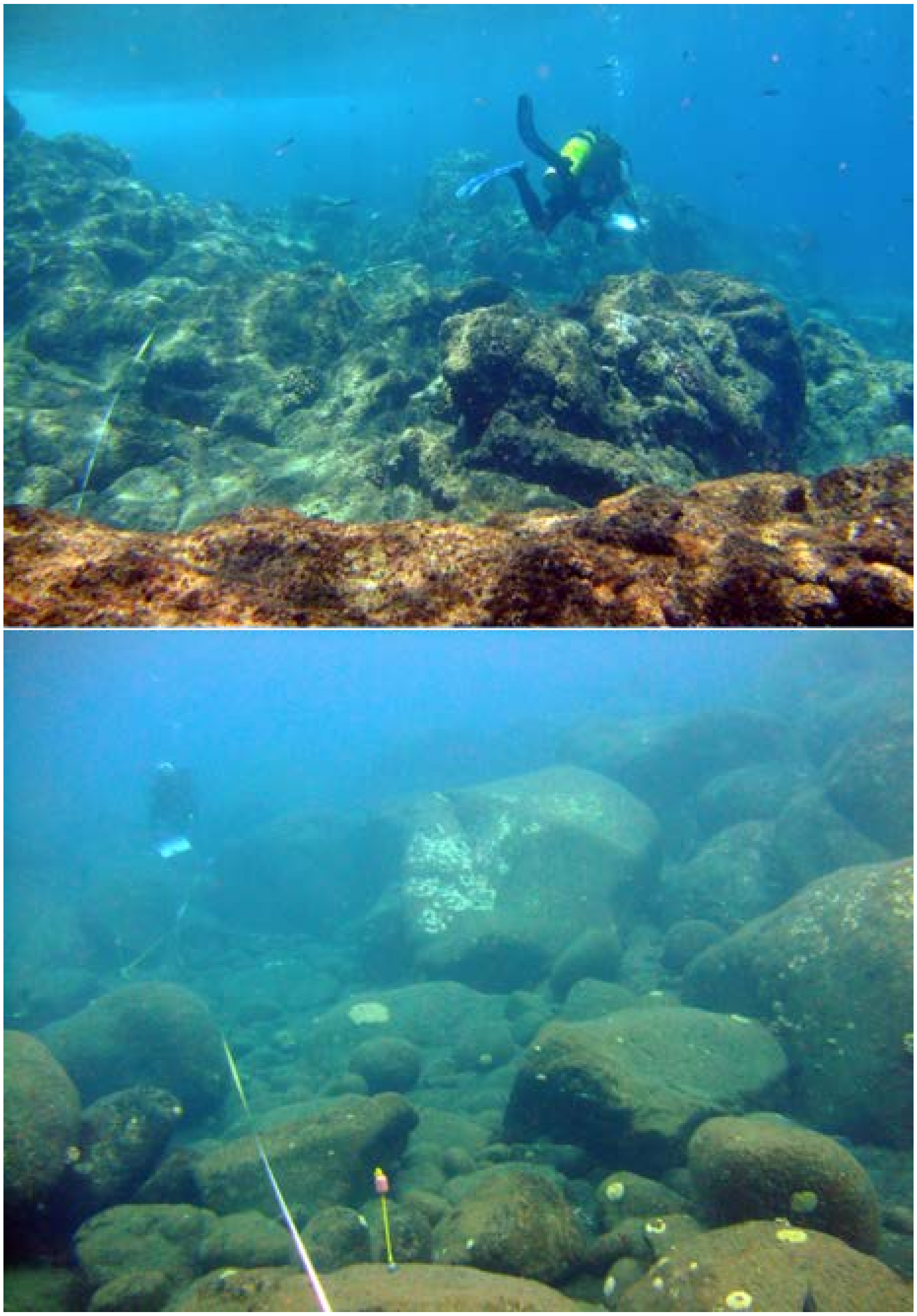


Figure 13. Examples of rock/boulder habitat. ***NOAA photos***

8. Reef rubble (RRB): Unconsolidated small (< 10 cm) fragments of coral skeletons or reef rock often colonized with filamentous or other macroalgae (Figure 14). This habitat often occurs landward of well-developed reef formations in reef crest or back reef zones.

Figure 14. Examples of rubble habitat. ***NOAA photos***

9. Spur and groove (SAG): Habitat with alternating sand and coral formations that are oriented roughly perpendicular to the shore, bank, or shelf (Figure 15). The coral formations (spurs) of this habitat type typically have a high, vertical relief relative to pavement with sand channels and are separated from each other by 1–5 m of sand or hard-bottom (grooves) substrate, although the height and width of these elements may vary considerably.

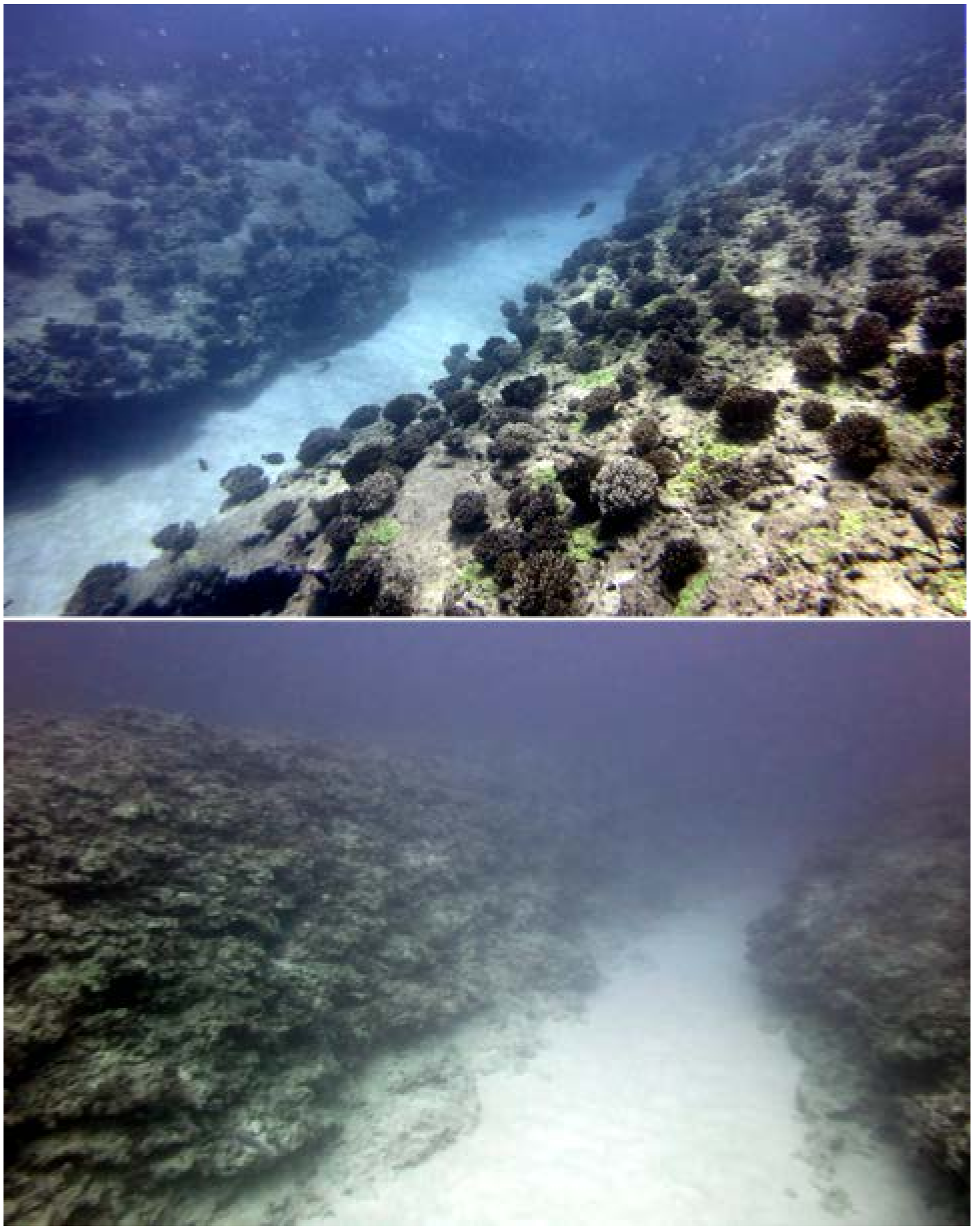


Figure 15. Examples of spur-and-groove habitat. ***NOAA photos***

10. Sand with scattered coral and rock (SCR): Primarily sand or seagrass bottom with scattered rocks or small, isolated coral heads that make up less than 10% of the general area (Figure 16). These habitats are generally not surveyed, but recording this habitat on the benthic data sheet. The only instance that this type of habitat will be surveyed is if the sand is actually only a thin layer coating hard substrate.

Figure 16. Examples of sand with scattered coral and rock habitat. ***NOAA photos***

Because of the great variety of reef habitats comprising ecosystems around the many Pacific islands surveyed by the ESD, a survey area may not fall neatly into one of these categories. The category with a definition that fits the majority of the habitat should be selected. At the surface, divers should discuss questionable habitat types and come to a consensus. The agreed-upon habitat type will be entered in the benthic survey data sheet (Figure 5**)** as well as the Dive and Navigation Information Sheet along with the site min and max depth based on the transect depths (Figure 50).

Adult coral surveys

Surveys of adult coral colonies are conducted within four 1.0 m wide × 2.5-m long segments centered along each transect (2 × 18 m transects, Figure 17), where each segment is numbered as follows: **Segment 0** = 0 – 2.5 m; **Segment 5** = 5.0 – 7.5 m; **Segment 10** = 10 – 12.5 m; **Segment 15** = 15 – 17.5 m.

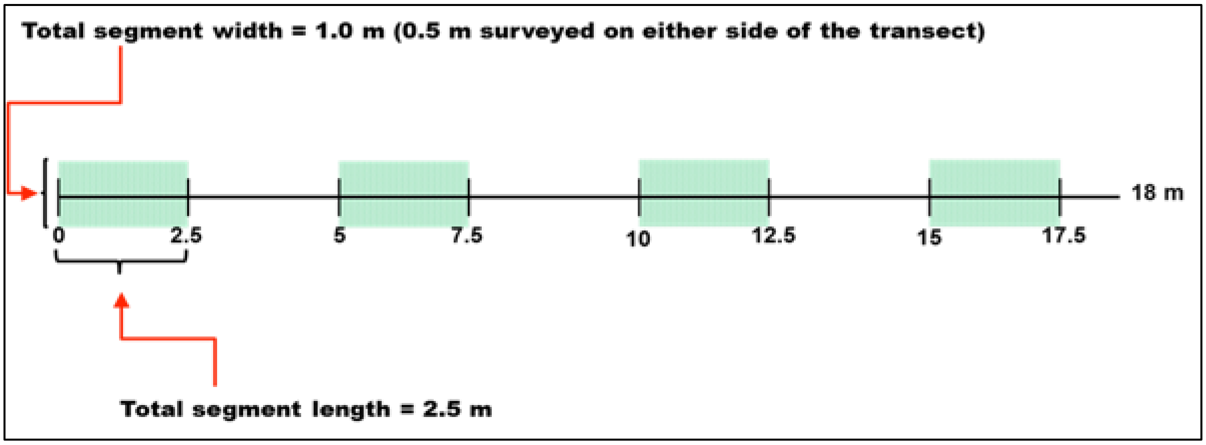


Figure 17. Example of the four survey segments on an 18-m transect.

Divers conducting the surveys should alternate segments to maintain a safe distance from their dive buddy (e.g. while working on transect #1, diver 1 completes Segments 0 and 10 while diver 2 completes Segments 5 and 15).

Only adult coral colonies (≥ 5 cm) with the center of the colony found within the boundaries of the segment are included in the survey (Figure 18). Large colonies which occupy > 75% of the total segment, but whose center falls outside of the segment, are also counted. All Scleractinian coral species are included in these surveys, as well as the hydrozoan "fire corals" (*Millepora* spp.) and the octocoral "blue coral" *Heliopora coerulea.*

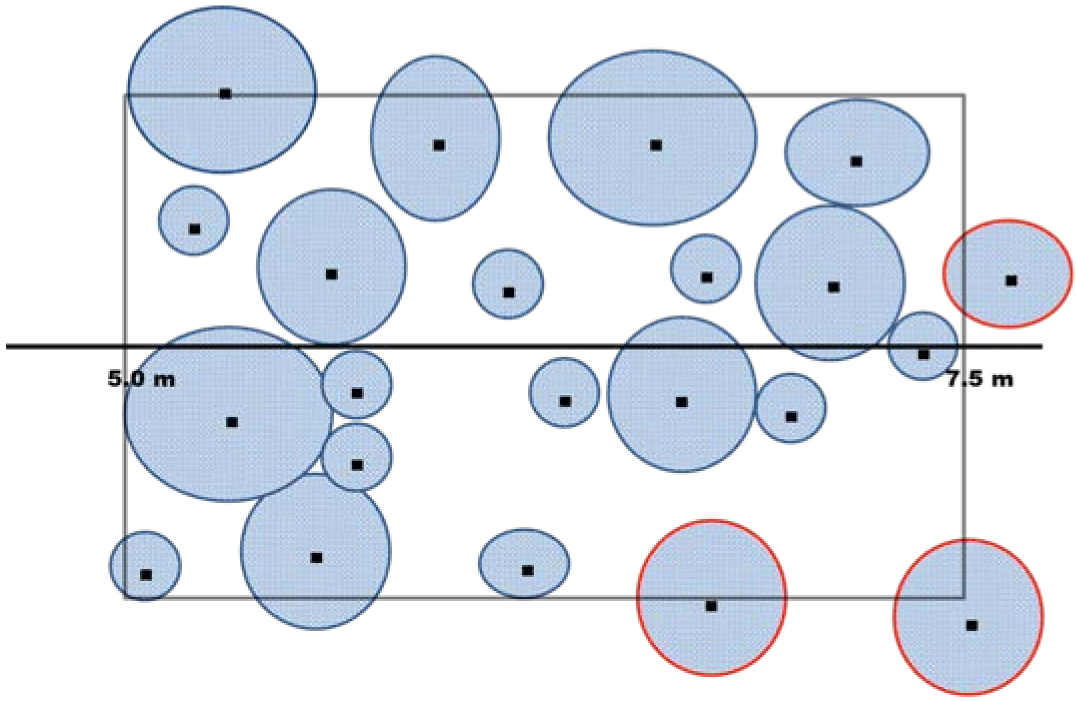


Figure 18. Diagram to show an example of the center rule used to survey coral colonies. Modified from Zvuloni et al. (2008).

Individual colony determination

Due to partial mortality, identification of an individual colony can be difficult. Considerations used to determine an individual colony include:

1) Are there pieces of live tissue on a common skeletal structure?
2) Are the pieces of tissue similar in color and polyp form?
3) Are the pieces of live tissue more than 10 cm apart?

If live tissue pieces are on a common skeletal structure, similar in color and polyp form, yet more than 10 cm apart, they are still considered as the same colony (Figure 19). If the live tissue pieces are not on a common skeletal structure and more than 10 cm apart, but similar in color and polyp form, they are considered different colonies. If the pieces of tissue are not similar in color and polyp form, they are considered different colonies, regardless of skeletal structure and the distance between pieces.

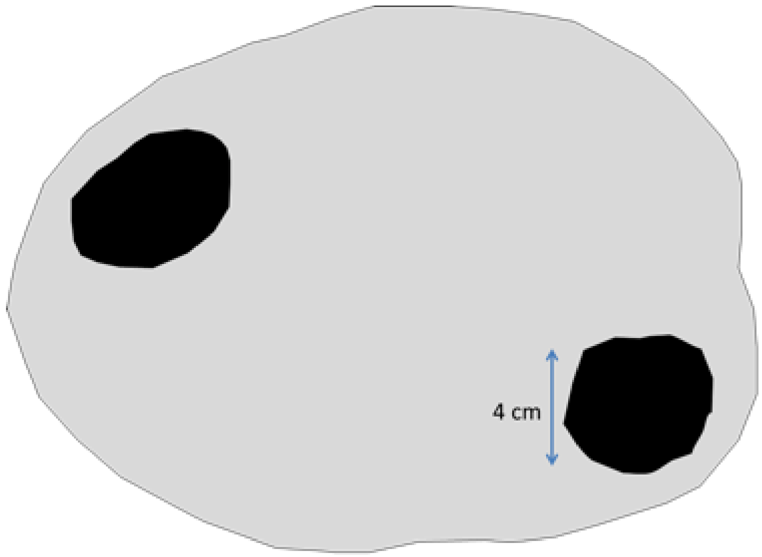


Figure 19. Schematic diagram of a coral colony with live tissue pieces represented by black areas and the previous colony margin represented by the grey area.

Special note: If a colony is a fragment of a larger colony and less than 5 cm, but cannot be defined as a juvenile, it must be included in the adult survey. These colonies are likely non-reproductive but have been shown to have similar growth rates as the intact adult tissue. By distinguishing juveniles from small colonies resulting from fission, estimates of juvenile abundance are improved.

Morphology

Identification of morphology (MORPH on datasheet) is essential to converting empirical length measurements from our field surveys to surface area estimates for each colony in the future. Estimates of surface area are necessary to model the reproductive potential of coral populations; thus the characterization of colony morphology is a critical component of benthic REA surveys. The morphology categories used for the purpose of our surveys include fifteen simplified versions of colony growth morphologies and geometric shapes (Table 2). Colony morphology may not always fit neatly into one of these 15 categories, however, the one which best describes the general shape of the colony should be recorded.

Table 2. Morphology categories identified during field surveys of adult coral colonies.

Morphology	Code	Description
Encrusting (flat)	EF	Adheres to a flat surface; “pancake glued to the bottom”
Encrusting (mounding)	EM	Adheres to a mounding surface (e.g. ledge); “frosting on a cake or barf on a rock”; this category also includes colonies that are encrusting inverted
Encrusting (columnar)	EC	Adheres to a relatively flat surface and also has columns; encrusting or spread out base or portion of the colony with “branches, knobs, columns or chimneys” (e.g. *Montipora capitata*);
Mounding	MD	Solid and similar in shape in all dimensions; Ellipsoid – small or large, sometimes spherical
Plating	PL	Forms simple plate extending outwards from the benthic substrate, akin to the shingle on a roof – note that this morphology denotes single, not multiple plates
Bifacial Plates	BP	Vertically oriented plates or thin “blades”
Foliose	FL	Plates that form whorls – usually multiple plates, “a head of lettuce”
Laminar	LM	Multiple plates on a larger structure; “shingles on a mound”
Laminar-columnar	LC	Combination of laminar and columnar morphologies, multiple plates on a larger structure with columns protruding from the top; “candles on a tiered birthday cake”; common for *Porites rus* and *Montipora capitate*
Branching	BR	Branches present; “fingers”
Knobby	KN	Stubby branches; “knuckles”
Columnar	CO	Forms columns of stumps that do not share a common base like branching corals generally do
Table	TB	Forms a table with one central leg attached to the substratum, common for *Acropora* spp. such as *A. cytherea*
Mounding lobate	ML	Mounding, vertically oriented lobes or “pork chops”; common for *Pavona duerdeni*
Disc (free living)	FR	Not attached to any substrate (e.g. *Fungia* sp.) including species that are considered branched free living –*Polyphyllia* sp.

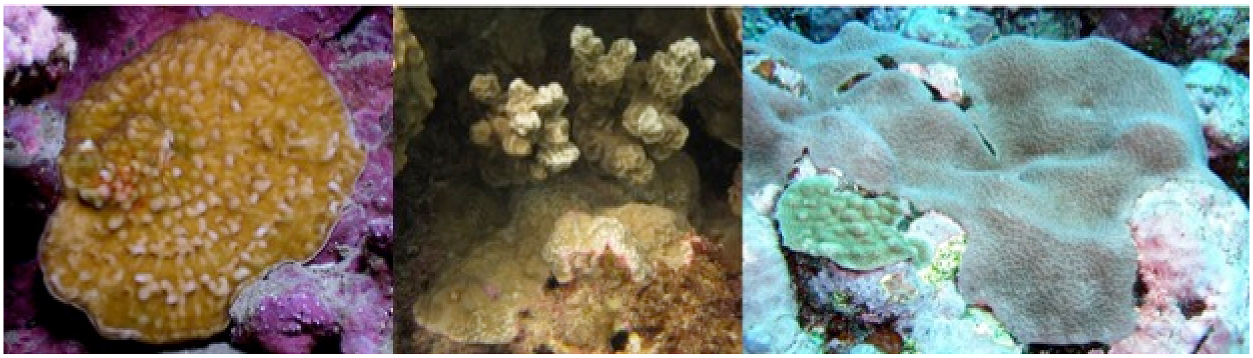


Figure 20. Example of encrusting coral morphologies: a) flat; b) columnar, c) mounding/massive. ***NOAA photos***

Figure 21. Example of (a) plating , (b) bifacial plating, and (c) foliose coral morphologies. ***Guamreeflife.com and NOAA photos***

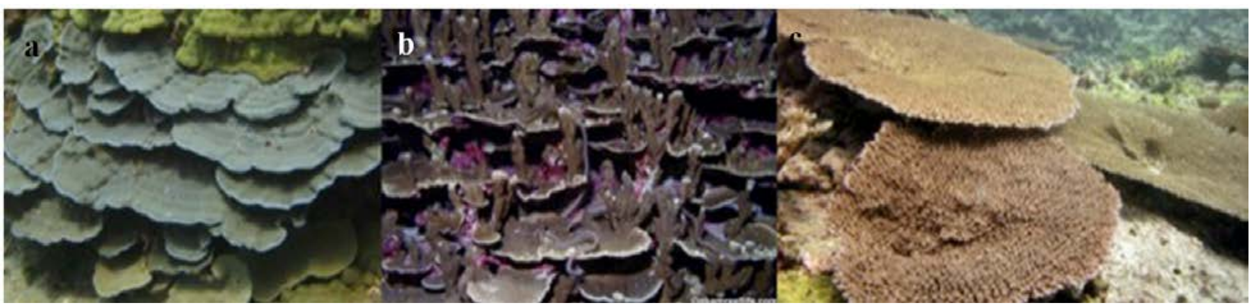


Figure 22. Example of (a) laminar, (b) laminar-columnar, and (c) tabular coral morphologies. ***Guamreeflife.com and NOAA photos***

Figure 23. Example of (a) massive/mounding and (b) mounding-lobate coral morphologies. ***NOAA photos***

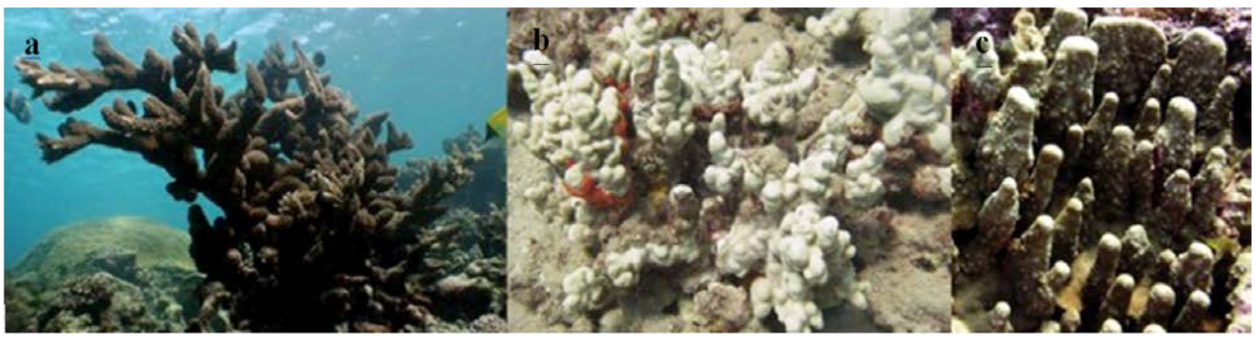


Figure 24. Example of (a) branching, (b) knobby, and (c) columnar coral morphologies. ***NOAA photos***


Figure 25. Example of a free living/disc coral morphology. ***NOAA photos***

Measurement of colony size

For adult colonies, the length of an entire colony (including partial mortality) is measured across the maximum diameter to the nearest centimeter (cm) (Figure 26). The diameter must be measured with respect to colony growth orientation rather from a planar perspective. For juveniles only, the width of the colony is taken as the maximum distance perpendicular to the length of the colony.

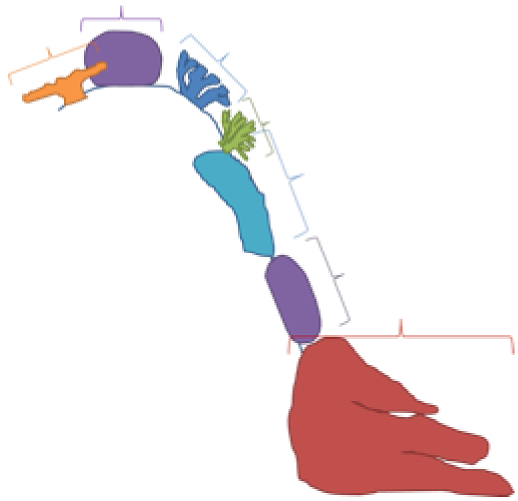


Figure 26. Schematic of maximum diameter measured depending on the orientation of various coral morphologies.

Partial mortality

Partial mortality is classified as either 'old dead' or 'recent dead' and estimated on each colony as a percent of colony surface area to the nearest 1 %, if possible. If a colony is entirely dead (in any combination of old dead and recent dead), do not measure the colony.

Old partial mortality ('% Dead' on datasheet; Figure 5) is defined as the non-living portion of a colony where the corallite structures are either gone or covered over by organisms that are not easily removed. This portion of the colony is where the live tissue is presumed to have died within the last few months to years or longer. The cause of old dead mortality is rarely known with certainty, and therefore not recorded.

Recent dead ('% Recent' on datasheet; Figure 5) is defined as the non-living portion of a colony in which the corallite structures are still intact (unless freshly bitten by a fish or abraded) and the exposed skeleton is either stark white or has only a very thin layer of sediment, biofilm (i.e. bacteria), diatoms, microalgae, or tiny turf algae. The presumption of recent dead mortality is that this portion of the colony has died within the last day, days, or months.

The cause of recent mortality ('RD Cause' on datasheet; Figure 5) is recorded, even if it must be recorded as unknown. The cause is identified to a general category and as a specific type (e.g. general = predation; specific = COTS predation). The 10 general causes of recent mortality are disease, predation, overgrowth, sediment necrosis, and type of damage (classified as – abrasion, broken, dislodged, or toppled), other, and unknown (described below). Within each of the 10 general categories, there are several specific sub-categories that further define the cause of recent mortality (Table 3).

When there are multiple causes of recent dead, be sure to attribute a % recent mortality to *each* cause.

Table 3. General and specific causes of recent dead, partial mortality.

General category	Code	Specific category	Code
Disease	DZGN		
		Acute tissue loss or white syndrome	WSY
		Sub-acute tissue loss	TLS
		Porites ulcerative white spot	PUS
		Banded fungal infection	BFI
		Brown band disease	BRD
		Black band disease	BBD
		Other	OTH
Predation	PRED		
		Crown of thorns	COTS
		Fish predation	FISH
		Gastropod predation	GAST
Overgrowth	OVRG		
		Algae (general)	ALGA
		Macroalgae	MACA
		Encrusting algae	ENCA
		Turf algae	TRFA
		Crustose coralline algae	CRCA
		Sponge	SPON
		Octocoral	OCTO
		Zoanthid	ZOAN
		Tunicate	TUNI
		Stony coral – Scleractinia and Milleporina sp.	CORA
Sediment necrosis	SEDI		
		*Categories apply to each damage type:	
Damage – Abrasion	DAMA	Anchor*	ANCH
Damage – Broken	DAMB	Rope*	ROPE
Damage – Dislodged (loose)	DAMD	Chain*	CHAN
Damage – Toppled	DAMT	Line*	LINE
		Net*	FNET
		Other*	OTHR
		Unknown*	UNKN
Other	OTHR	Other	OTHR
Unknown	UNKN	Unknown	UNKN

Recent mortality causes: Disease (DZGN)

Diseases that cause tissue loss lesions leave behind a recently dead area (small or large) of exposed coral skeleton. These disease types include the following (each are described specifically below): acute tissue loss or White syndrome (WSY), sub-acute tissue loss (TLS), *Porites* ulcerative white spot (PUS), banded fungal infection (BFI), brown band disease (BRD), black band disease (BBD), and other (OTH). If recent dead percent is recorded and disease is noted, but the diver does not define the disease type, then the disease general code (DZGN) should also be recorded in the disease specific column.

<u>Acute tissue loss or White syndrome (WSY):</u> Acute tissue loss or White syndrome is a collective term used to describe lesions characterized by the rapid loss of tissue, leaving behind a sharp, clean band, where tissue is completely removed from the skeleton (Figure 27). A progression of filamentous and turf algae often covers the exposed skeleton, illustrated by a color gradient from bare skeleton to brown as the fouling community develops.

Figure 27. Example of acute tissue loss or White syndrome. *NOAA photos*

<u>Sub-acute tissue loss (TLS):</u> Sub-acute tissue loss is a collective term to describe lesions resulting in slow but progressive loss of tissue (Figure 28). It is distinguished from white syndrome by the narrow width of the zone of recently exposed skeleton. Bare white skeleton is often not present, but instead has only a very thin layer of sediment, biofilm (i.e. bacteria), diatoms, microalgae or tiny turf algae.

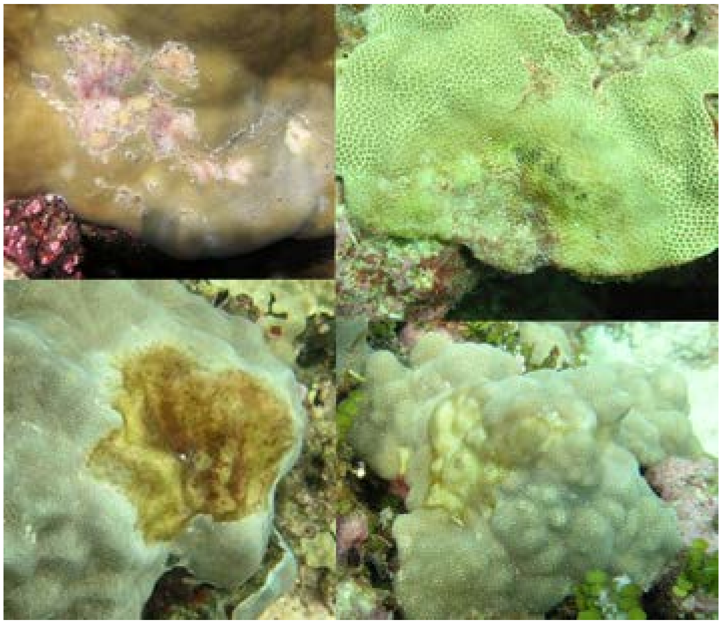


Figure 28. Examples of subacute tissue loss (TLS). ***NOAA photos***

Porites ulcerative white spot (PUS): These multifocal patterns of tissue loss expose spots of bare white skeleton (Figure 29). Lesions are typically small (≤ cm diameter) and regularly ovoid. These lesions may start as bleached spots. A colony may contain both bleached lesions and lesions devoid of tissue.

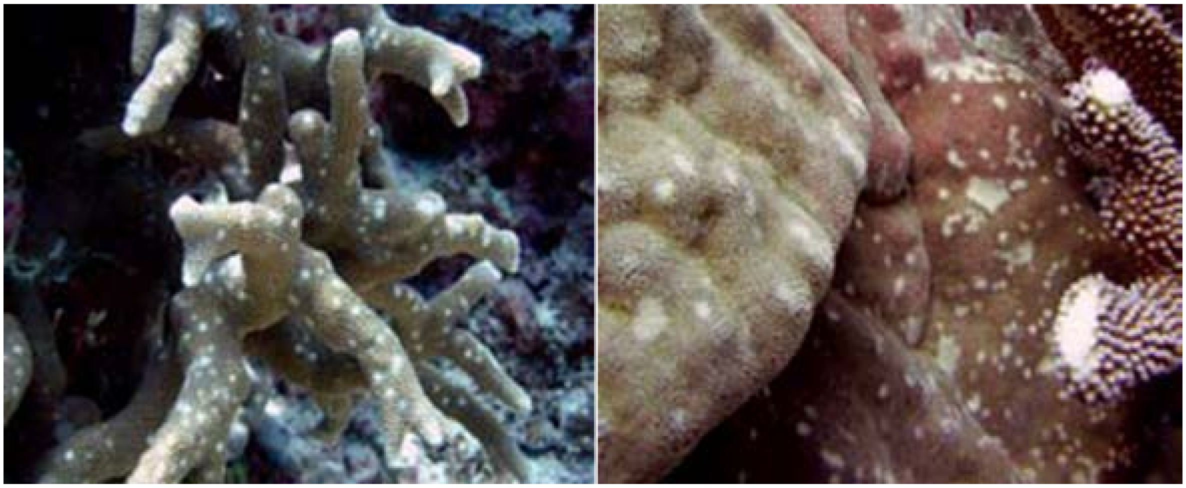


Figure 29. Examples of Porites ulcerative white spot (PUS). ***NOAA photos***

Banded fungal infection (BFI): Diseased colonies exhibit a distinct yellow to bright green mat about 1– 3 cm wide on the coral tissue (Figure 30). A progression of filamentous and turf algae generally appears on the exposed skeleton as the tissue is lost. The unaffected coral tissue appears normal in color and morphology.

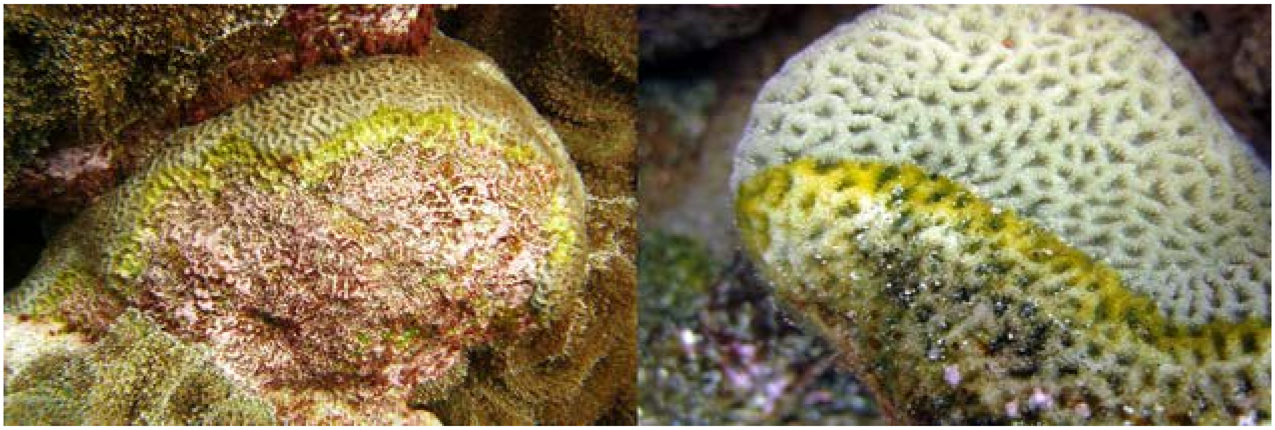


Figure 30. Examples of banded fungal infection (BFI). ***NOAA photos***

<u>Brown band disease (BRD):</u> Brown band disease is characterized by bands composed of ciliates, varying from light to dark brown with ciliate density (Figure 31). A narrow white band may be present between live coral tissue and brown band. The rate of progression is rapid (20–100 mm/day).

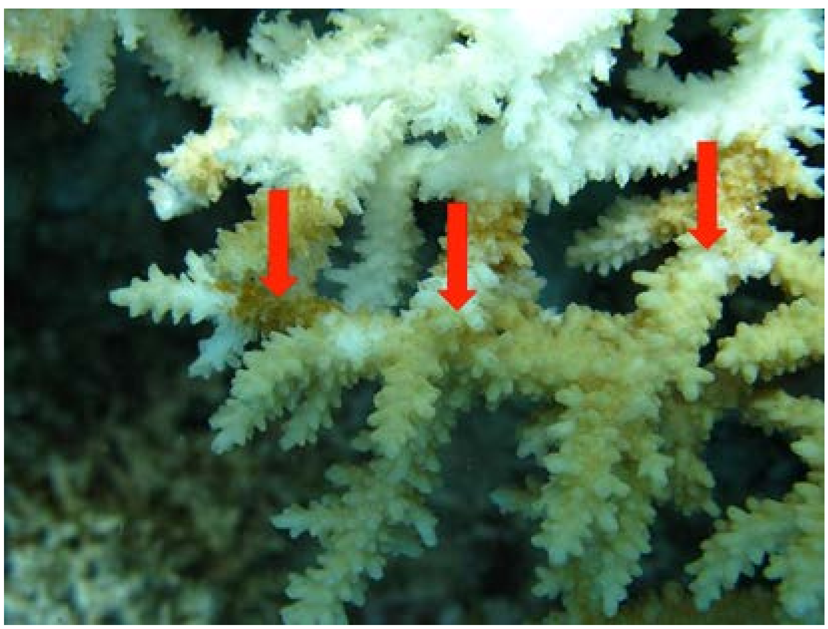


Figure 31. Example of brown band disease (BRD). ***NOAA photos***

<u>Black band disease (BBD):</u> This condition is characterized by a distinct black to grey mat, ~ 0.5– 4 cm wide, on the living coral tissue that leaves behind the bare white skeleton (Figure 32). The band color can vary from black to gray or reddish-brown. The unaffected coral tissue appears normal in color and morphology. The skeleton distant from the tissue front often becomes progressively brown as it becomes colonized by a fouling community. Lesions are variable in size and shape.

Figure 32. Examples of black band disease (BBD). ***NOAA photos***

Other (OTH): This category should be used for the occurrence of disease that causes a tissue loss lesion, but is not described by the six disease types.

Recent mortality causes: Predation (PRED)

Crown of thorns sea star (COTS): The lesions caused by crown of thorn sea star predation are evident by the conspicuously shaped scars, forming focal-to-diffuse tissue loss lesions that expose the bare coral skeleton (Figure 33). Recent lesions are white and generally exhibit discrete borders. Feeding scars often exhibit a scalloped border. The border may show visible strings of tissue and mucus when the scar is fresh. Usually crown of thorn sea stars can be seen in the survey area.

Figure 33. Examples of crown-of-thorns sea star (COTS) predation. ***NOAA photos***

Fish (FISH): Recent lesions caused by fish predation are predominantly inflicted by corallivorous fishes (parrotfish, pufferfish, and butterfly fish families) (Figure 34). Fish bites are very distinctive gouges or scrapes. These bite marks may also involve damage of coral skeleton. Do not record damselfish bites/chimney or "blenny kisses".

Figure 34. . Examples of fish (FISH) predation. *NOAA photos*

<u>Gastropod (GAST):</u> Recent lesions caused by gastropod predation are focal, multifocal or diffuse scars that expose the bare coral skeleton (Figure 35). Feeding scars have an irregular border. Shredded strings of tissue may be visible. Snails are often found on neighboring colonies if not immediately visible beside the feeding scars.

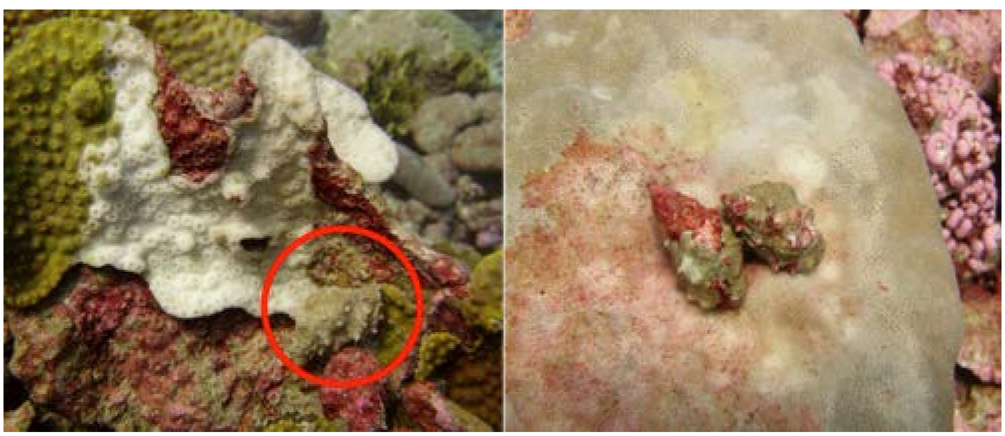


Figure 35. Examples of gastropod predation (GAST). *NOAA photos*

Recent mortality causes: Overgrowth (OVRG)

Live coral tissue can be overgrown by a variety of organisms. A zone of white exposed skeleton between the overgrowing organism and live coral tissue is present (Figure 36). Specific types of overgrowth include: algae (general; ALGA), macroalgae (MACA), encrusting algae (ENCA), turf algae (TRFA), CCA (CRCA), sponges (SPON), octocoral (OCTO), zoanthid (ZOAN), tunicates (TUNI), and stony coral (CORA). The amount of overgrown coral (estimated by percent recent dead) should only be measured as the small amount that is visible revealed underneath the overgrowing organism or peeled back to reveal the lesion (Figure 36).

Figure 36. Example of a recent dead lesion caused by overgrowth of Palythoa sp. The amount of colony affected is represented by the area outlined in green. *NOAA photos*

Recent mortality causes: Sediment necrosis (general; SEDI)

Recent dead lesions caused by sedimentation are characterized by a diffuse area of tissue loss associated with fine sediment accumulating in hollows on coral surfaces, and on coral polyps and tissue. This visible sediment deposition, which is at times accompanied by mucus secretion and pigmentation response, is a key identifying characteristic of mortality due to sedimentation.

Recent mortality causes: Physical damage

Physical damage to corals fall into four general categories: 1) abrasion (DAMA); 2) broken (DAMB); 3) dislodged or loose (DAMD); and 4) toppled (DAMT) (Table 4). Each of these four general physical damage categories can be further identified by five specific causes (anchor (ANCH), rope (ROPE), chain (CHAN), line (LINE), net (FNET)), or if the specific cause cannot be identified, other (OTHR) and unknown (UNKN). The specific cause is commonly unknown unless the marine debris is found directly on the colony or located nearby.

Table 4. Categories of physical damage. Damage can be a cause of recent mortality and/or recorded for overall colony condition.

Damage	**Description**
Abrasion	Physical damage to colony tissue and possibly skeletal structure due to contact with a rope or a line or other object
Broken	A portion of the colony is broken off of the remaining intact colony leaving a lesion
Dislodged or loose	The orientation of the colony is upright but not secured to the substratum
Toppled	The colony is not upright and is lying on its side or upside down

These should only be listed in the recent dead cause columns when associated with a recent dead lesion and given a percentage of recent dead partial mortality. Physical damage associated with old dead area should be listed as a condition (see description below).

Condition

When assessing colony condition ('Condition' on data sheet), corals are examined for instances of disease, bleaching, and physical damage distinct from the partial mortality assessment (Table 5). All condition codes require an assessment of extent ('Ex' on the datasheet) as % of colony affected estimated to the nearest 1%. The following condition codes require assessment of severity: Bleaching (BLE), patching bleaching (BLP), skeletal growth anomalies (SGA), and *Porites* trematodiasis (PTR). Severity values (Sv on data sheet) range from 1 to 5 (e.g. for bleaching: 1 = slight paling; 5 = stark white skeleton) for BLE, BLP, SGA, and PTR only. Unlike recent dead, the coral tissue is still alive and the polyps are visible. The default code in the data entry program is NDZ, which is defined as no condition recorded.

Table 5. List of conditions that may be found on coral colonies (* = denotes condition codes requiring estimates of severity, in addition to extent).

Code	Condition Description	Affected
NDZ	No disease	Corals, octocorals
ALG	Algal infection	Corals
FUG	Endolithic fungal infection	Corals
PDS	*Porites* discolored swelling	*Porites sp.*
SGA	Skeletal growth anomalies*	Corals
PTR	*Porites* trematodiasis*	*Porites sp.*
PRS	Pigmentation response	Corals
BIN	Barnacle infestation	Corals
TIN	Tube worm infestation	Corals
OTH	Other	Corals
BLE	Bleaching*	Corals, octocorals
BLP	Patchy bleaching*	Corals, octocorals
DIS	Discolorations other than bleaching	Corals, octocorals
DAMA	Physical Damage – abrasion	Coral
DAMB	Physical Damage – broken	Coral
DAMD	Physical Damage – dislodged	Coral
DAMT	Physical Damage – toppled	Coral

Algal infection (ALG)
An algal infection is the colonization and overgrowth of living coral tissue by various species of algae. With heavy overgrowth, underlying coral tissue usually dies, leaving bare skeleton (Figure 37). Abrasion from the algae may cause a pigmentation response.

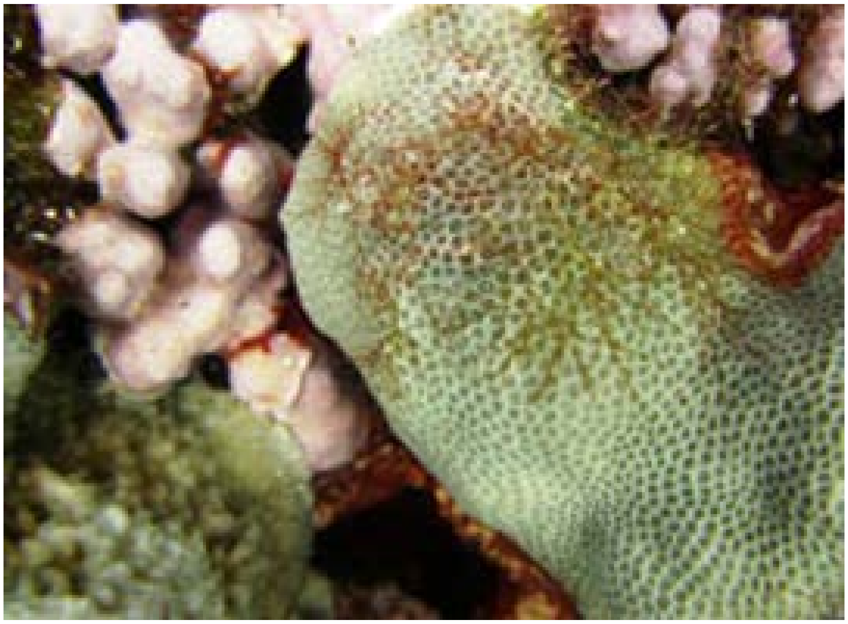


Figure 37. Example of algal infection (ALG). ***NOAA photos***

Endolithic fungal infection (FUG)

An endolithic fungal infection is characterized by the discoloration of coral live tissue (Figure 38). The discoloration can be identified by multifocal or diffuse areas of brown, reddish brown or purple colored tissue discoloration.

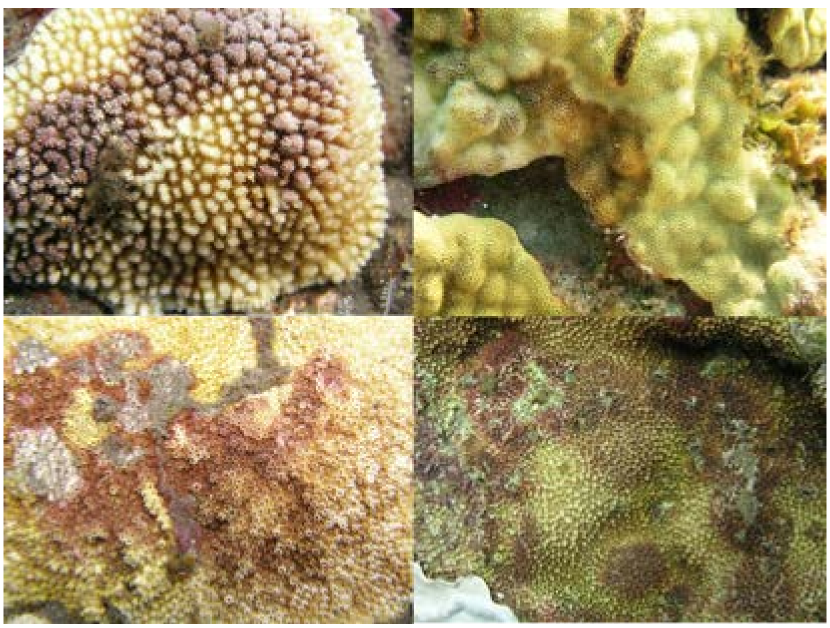


Figure 38. Examples of endolithic fungal infection (FUG). ***NOAA photos***

Porites discolored swelling (PDS)
Porites discolored swelling is characterized by distinct irregular areas of swollen, discolored tissue. Hyperpigmentation is occasionally visible at the border (Figure 39). Corallite structure is not abnormal, but tissue looks puffy.

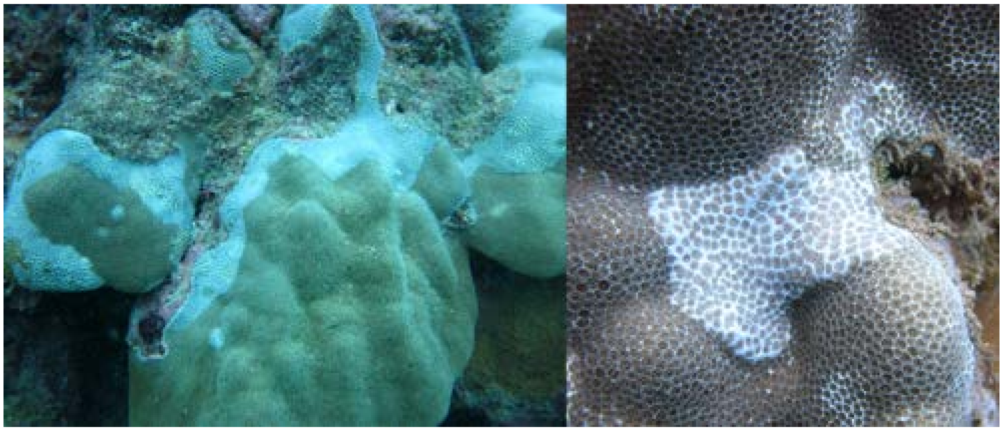


Figure 39. Examples of Porites discolored swelling (PDS). ***NOAA photos***

Skeletal growth anomalies (SGA)
Skeletal growth anomalies are characterized by focal to multifocal and circular to irregularly shaped lesions comprising abnormally arranged, enlarged skeletal elements (Figure 40). These anomalies typically protrude above the colony surface and the surface rugosity visibly differs from healthy tissue. Corallites might remain normal size, but the spacing between corallites can increase. The pigmentation of the anomalies may be normal or slightly pale. Both extent and severity are recorded for this condition. Severity reflects how anomalous the growth is in shape, height, etc.

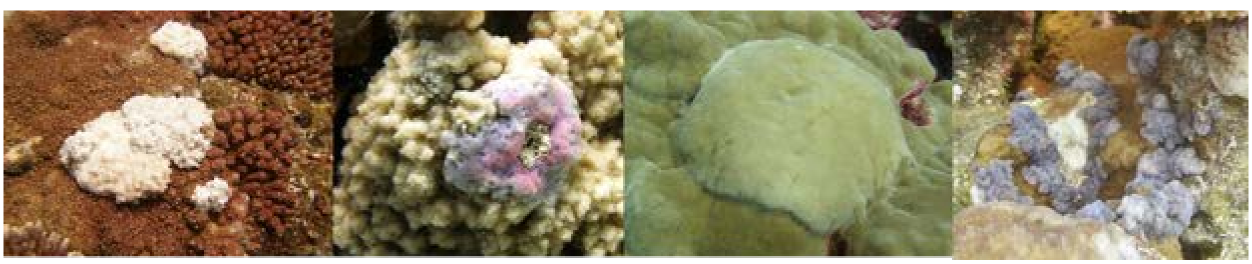


Figure 40. Examples of skeletal growth anomalies (SGA). ***NOAA photos***

Porites trematodiasis (PTR)
Porites trematodiasis is characterized by multifocal, distinct pink to white small (2 mm) areas of tissue swelling (Figure 41). The swelling of one or few polyps is in response to encysted parasitic trematodes. These trematode cysts are often clustered. The extent reflects the amount of colony surface area covered by the pink patches, while severity is how ‘angry’ (i.e. swollen and pigmented) the pink patch appears.

Figure 41. Examples of Porites trematodiasis (PTR).

Pigmentation response (PRS)

Pigmentation response is characterized by bright pink patches of discolored, swollen tissue, often occurring in irregular shapes and patterns, scattered on the surface of the colony or adjacent to the sediment/algal margins of a colony (Figure 42). Often these lesions appear to be associated with small areas of tissue loss or filamentous algal infections.

Figure 42. Examples of pigmentation response (PRS). ***NOAA photos***

Barnacle infestation (BIN)

Barnacle infestations are characterized by numerous barnacles embedded in a coral colony (Figure 43), resulting in noticeable white spots.

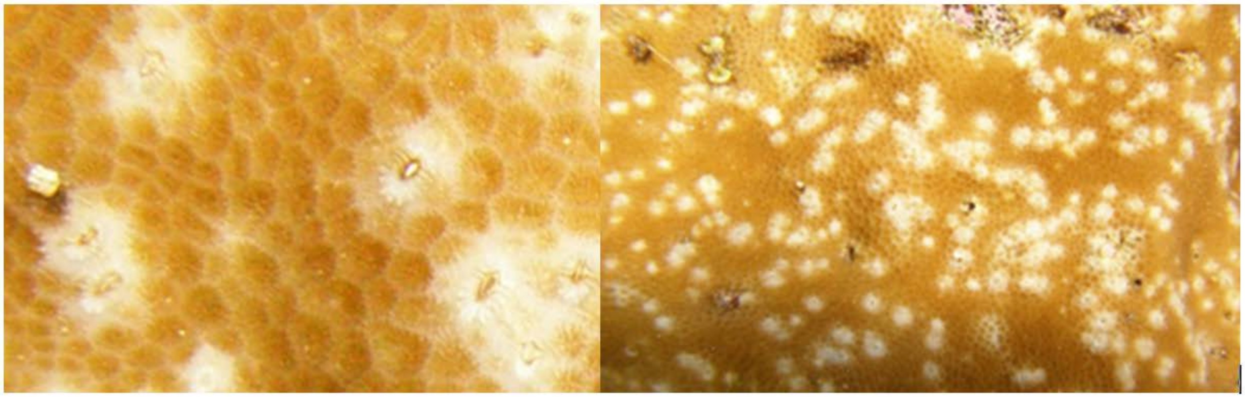


Figure 43. Examples of barnacle infestations (BIN). ***NOAA photos***

Tube worm infestation (TIN)
Tube worm infestations are characterized by numerous tubeworms embedded in a coral colony (Figure 44). There are often noticeable white spots or protruding tubes.

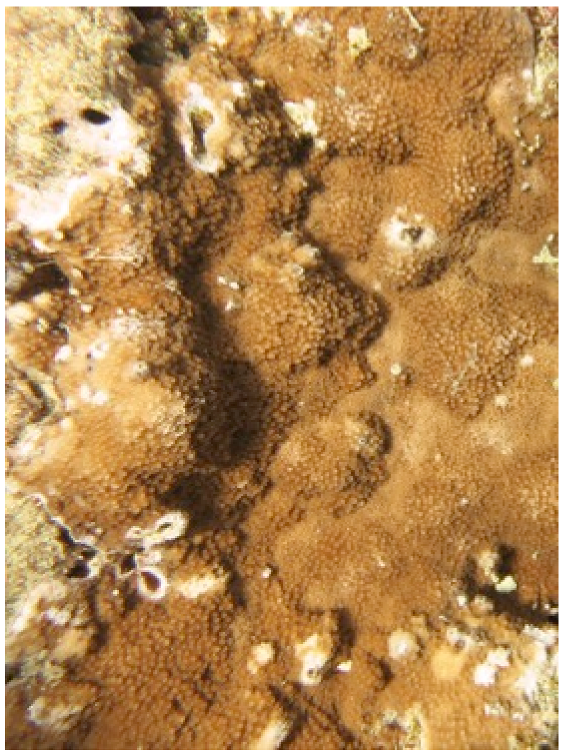


Figure 44. Example of a tube worm infestation (TIN). ***NOAA photos***

Bleaching (BLE)
Coral bleaching is characterized by a reduction or absence of coloration within coral tissues due to the loss of zooxanthellae (Figure 45). Severe bleaching is usually associated with environmental stress, such as unusual levels of temperature, light, and/or salinity. However, coral tissue is still alive and the polyps are visible. If varying severity of bleaching is observed (i.e. a gradient of paling to bleached), score as the average severity observed over the entire colony.

Figure 45. Examples of coral bleaching (BLE). ***NOAA photos***

Patchy bleaching (BLP)

Patchy bleaching is characterized by unusual, diffuse patterns of bleaching that do not appear to be a specific response to thermal or other environmental stress (Figure 46). This condition may be caused by intercellular bacterial pathogens. The coral tissue is still alive and the polyps are visible. Both extent and severity are recorded. Margins between bleached and unbleached tissue are typically very distinct, while BLE is typically characterized by a gradient with paling present.

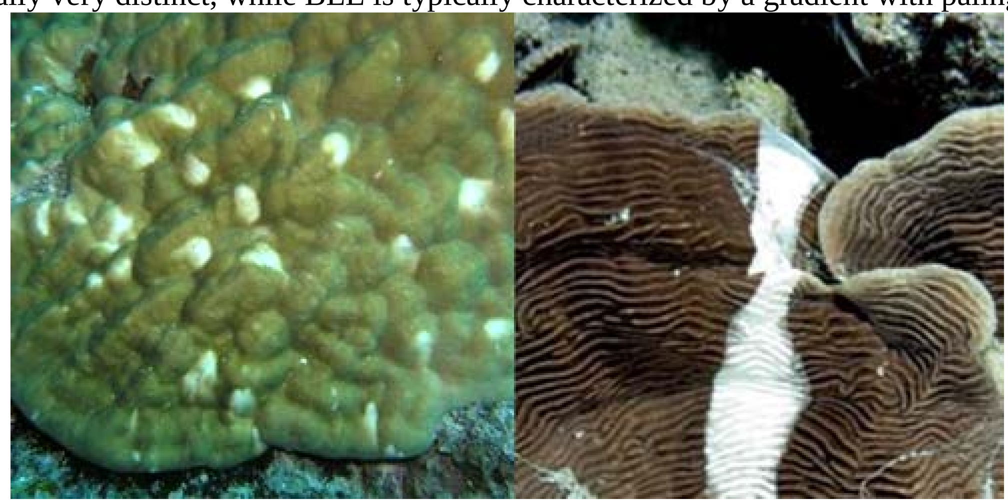


Figure 46. Examples of patchy coral bleaching (BLP). ***NOAA photos***

Discolorations other than bleaching (DIS)

Discoloration lesions (other than bleaching and *Porites* pigmentation responses) are characterized by abnormally colored patches that are often bright and occurring in irregular shapes and patterns. Patches are scattered on the surface of the colony or adjacent to the sediment/algal margins of a colony (Figure 47). Often these lesions appear to be associated with small areas of tissue loss or filamentous algal infections.

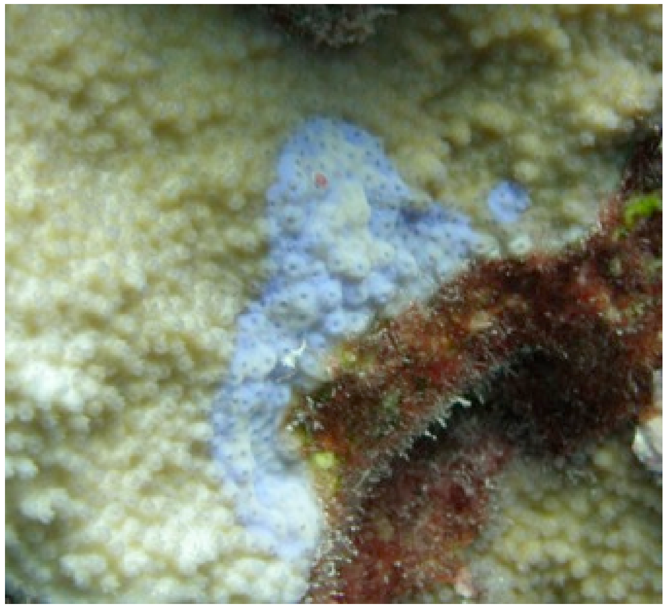


Figure 47. Examples of discolorations other than bleaching (DIS). ***NOAA photos***

Other (OTH)
Any notable or atypical feature not described above and not associated with recent mortality will be recorded as other.

CCA and Alcyonarian disease surveys

CCA diseases and Alcyonarian disease are surveyed within the same four segments per transect as the adult coral surveys are completed are completed are completed. Table 6 lists these diseases and their corresponding codes. In each segment, the occurrence of a specific disease is identified and the lesion is measured (maximum diameter). For example, if four separate lesions of coralline cyanobacterial disease are found within a segment, the code CCD is listed on four separate lines of the data sheet, along with the measurement of each lesion.

Table 6. Types of Alcyonarian disease and crustose coralline algae diseases and the organisms affected.

Code	Disease	Affected
AND	Alcyonarian necrotizing disease	Octocorals
CCD	Coralline cyanobacterial disease	CCA
CFD	Coralline fungal disease	CCA
CLD	Coralline lethal disease (aka Coralline White Band Syndrome)	CCA
CLOD	Coralline lethal orange disease	CCA
CRS	Coralline ring syndrome	CCA

Presence of Anthozoans

Presence of colonies from the class Anthozoa (Table 7) within each segment should be noted. For example, if one or more colonies of the following genus/species are found within a segment, the species/genus code should be recorded on the data sheet one time. No other information is recorded (i.e. number of colonies and measurements are not recorded).

Table 7. List of Anthozoans.

Subclass Alcyonaria	**Code**	**Order**
Palythoa sp.	PASP	Zoantharia
Protopalythoa sp.	PRSP	Zoantharia
Zoanthus sp.	ZOSP	Zoantharia
Cladiella sp.	CLSP	Alcyonacea
Dendronephthya sp.	DESP	Alcyonacea
Lobophytum sp.	LOBP	Alcyonacea
Pachyclavularia sp.	PACH	Alcyonacea
Sarcothelia sp.	SRSP	Alcyonacea
Sarcophyton sp.	SARS	Alcyonacea
Sinularia sp.	SISP	Alcyonacea
Stereonephthya sp.	STES	Alcyonacea
Soft coral	SOFT	Alcyonacea
Octocoral	OCTO	Alcyonacea
Distichopora sp.	DISS	Anthoathecata
Stylaster sp.	STYL	Anthoathecata
Corallimorpharian	CORL	Corallimorpharia
Rhodactis	RHSP	Corallimorpharia
Wire coral sp	WIRE	Antipatharia

Juvenile coral surveys

Surveys of juvenile coral colonies (< 5 cm) are conducted within three numbered 1.0 × 1.0 m segments centered along each transect (Figure 48), where each segment is numbered as follows: **Segment 0** = 0 – 2.5 m; **Segment 5** = 5.0 – 7.5 m; **Segment 10** = 10 – 12.5 m. No juvenile coral survey is performed from 15.0 to 16.0 m along each transect.

As with adult colonies, the center of the juvenile colony must be located within the boundaries of the segment to be included in the survey. Juvenile colonies should be distinguished in the field by a distinct tissue and skeletal boundary (not a fragment of larger colony). Each colony is measured for size by recording both the maximum and perpendicular diameter to the nearest 2 mm. These measurements are used to determine surface area.

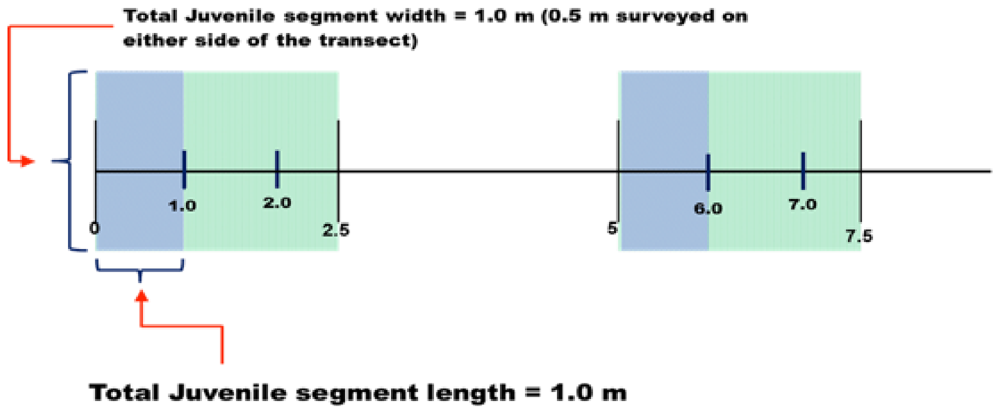


Figure 48. Diagram of two juvenile coral survey segments in relation to those surveyed for adult corals.

Benthic photo surveys

Photoquadrats are used to derive estimates of benthic cover. The first photo taken at each REA site is a photo of the slate with the dive site ID. The diver should utilize their slate to white balance the camera at this time. The diver should clearly denote the beginning of transects 1 and 2 by photographing one finger or two fingers, respectively, before collecting the photoquad images along that transect. The photoquadrat consists of a high-resolution digital camera mounted on a photoquadrat pole. The diver should take proper care to photograph the image perpendicular to the reef and not at an angle (Figure 49**Error! Reference source not found.**). The diver-photographer should look at the camera viewfinder during and after taking pictures to ensure that orientation of the monopod is correct (Figure 49**Error! Reference source not found.**) and that the images are not blurry. Photoquadrat images are collected along the same two transects used for coral surveys at one meter intervals, starting at 1 m and progressing to the 15-m mark (images are not collected at the 0 m mark). This provides a total of 15 images per transect and 30 per site.

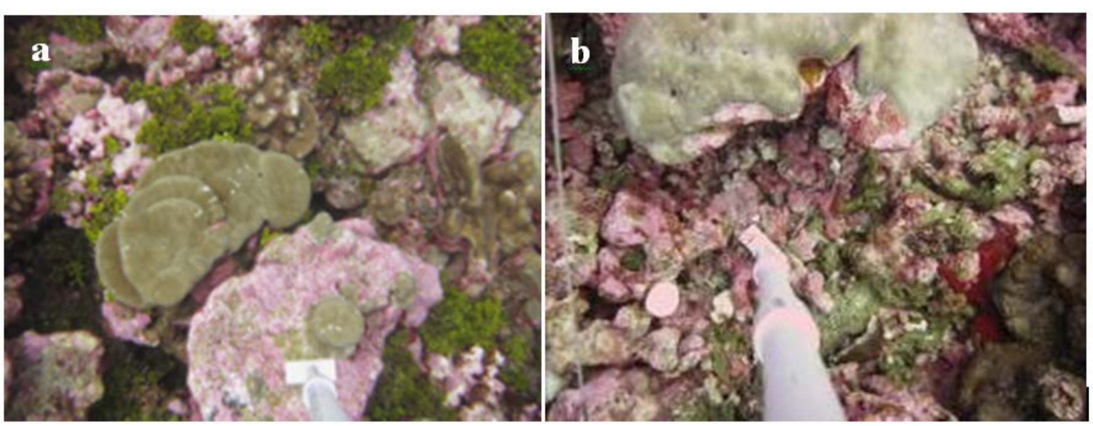


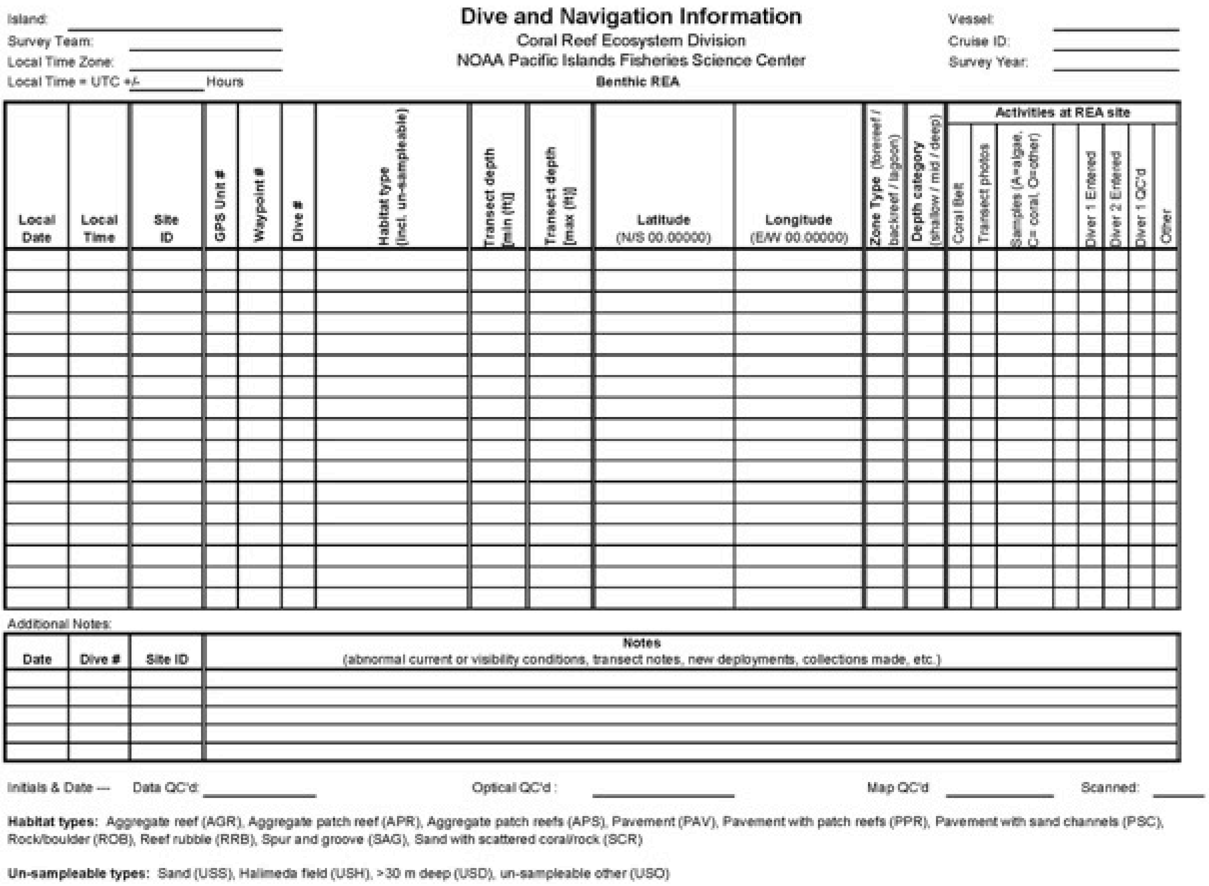
Figure 49. Examples of (a) ideal and (b) incorrect monopod placements. ***NOAA photos***

If the meter stick is crooked (Figure 49b), an object is in the way, or the image is blurry, another photo should be taken and the original photo deleted. If the bad photo is not deleted in the field, it should be deleted after the images are downloaded.

Dive and Navigation Information

The Dive and Navigation Information form (Figure 50) is used to record descriptions of benthic REA sites surveyed during each diving operation day. A new sheet should be filled out each day as dives are completed. The sheet is turned in to the data management person at the end of each dive day. These sheets serve as permanent records. The following information is recorded:

- **Island**: Island or atoll being surveyed (e.g., French Frigate Shoals or Tutuila Island)
- **Local Time Zone (example)**: PST (Pacific Standard Time)
- **Local Time = UTC +/- *x*** (e.g., *x* equals + 10 hours in the MHI/NWHI**;** check with the Data Manager to obtain appropriate value of *x* per island/jurisdiction)
- **Small Boat**: Current small dive boat (e.g., HI-2, HI-3)
- **Cruise ID**: The 6-character code for the current cruise (e.g., HA-11-02)
- **Survey Year**: The current year (e.g., 2011)
- **Local Date**: The date at current location
- **Local time**: The time at current location
- **Island 3-ltr Code**: The 3-letter island code (e.g., TUT)
- **Site ID (# only)**: The 4- or 5-digit code for current site (e.g., 102A)
- **GPS Unit #**: Each dive team has a GPS with an assigned number (e.g., Benthic A).
- **Waypoint #**: The waypoint marked in the GPS corresponding to the dive site. Once the site is marked in the GPS, the name should be changed from the number automatically generated by the GPS unit (e.g., 014) to the Site ID name, omitting the letter *A* (e.g., TUT-102).
- **Dive #**: Cumulative site number of the day (e.g., 1, 2, 3)
- **Habitat type**: Either taken from the Benthic Data Sheet (Figure 5), or, if the site is determined to be unsurveyable because of unsuitable habitat or depth, the designations Sand, *Halimeda*, too deep, or Other will be used. The habitat codes are listed at the bottom of this form.
- **Minimum and Maximum Depth**: These are minimum and maximum depth of the site in feet.
- **Latitude and Longitude:** Geographic coordinates for the position taken by the coxswain with the GPS directly over the dive site, once the divers have descended and set the surface buoy. This position should be taken directly from the GPS and should correspond to the coordinates saved under the Waypoint Number.
- **Zone Type**: Forereef (F), backreef (B), or lagoon (L)
- **Depth Category**. Recorded as shallow (S), mid-depth (M) or deep (D). Can be abbreviated as S, M or D. Min and max depth are captured by each diver on the underwater data sheets (Figure 5).
- **Coral belt**: Check if completed
- **Transect Photos**: Initials of the diver that took benthic photos
- **Samples:** Indicate whether water, coral, or algae samples were taken
- **Additional Notes**: This space can be used to record any additional information judged to be important by data collectors.



Island: ______

Survey Team: ______

Local Time Zone: ______

Local Time = UTC +/- ______ Hours

Dive and Navigation Information

Coral Reef Ecosystem Division
NOAA Pacific Islands Fisheries Science Center
Benthic REA

Vessel: ______

Cruise ID: ______

Survey Year: ______

Local Date	Local Time	Site ID	GPS Unit #	Waypoint #	Dive #	Habitat type (incl. un-sampleable)	Transect depth [min (ft)]	Transect depth [max (ft)]	Latitude (N/S 00.00000)	Longitude (E/W 00.00000)	Zone Type (forereef / backreef / lagoon)	Depth category (shallow / mid / deep)	Activities at REA site							
													Coral Belt	Transect photos	Samples (A=algae, C= coral, O=other)		Diver 1 Entered	Diver 2 Entered	Diver 1 QC'd	Other

Additional Notes:

Date	Dive #	Site ID	Notes (abnormal current or visibility conditions, transect notes, new deployments, collections made, etc.)

Initials & Date — Data QC'd: ______ Optical QC'd : ______ Map QC'd ______ Scanned: ______

Habitat types: Aggregate reef (AGR), Aggregate patch reef (APR), Aggregate patch reefs (APS), Pavement (PAV), Pavement with patch reefs (PPR), Pavement with sand channels (PSC), Rock/boulder (ROB), Reef rubble (RRB), Spur and groove (SAG), Sand with scattered coral/rock (SCR)

Un-sampleable types: Sand (USS), Halimeda field (USH), >30 m deep (USD), un-sampleable other (USO)

Figure 50. Sample of the Dive and Navigation Information data sheet used at the benthic REA sites.

Archiving Photos

After each day's field operations, benthic images are uploaded to the data server and must be stored in a specific file folder format (detailed in Appendix A2.1). A directory is designated on the shared drive for storing all benthic photos. Directory organization, for example, should follow the one also used on the main ESD server: V:\Cruise\CruiseData\HA1008 MHI\Optical\MOL\REA\BENTHIC\MOL-160. Located in each REA site folder are two folders: *Photo_Quads* and *Site_Photos*. In each of these folders are subfolders for each replicate survey (transect 1 and 2), where all benthic and site photos are uploaded. In addition, in an *OTHER* folder at the REA directory level, all photos that are not benthic photoquad images nor site photos should be stored in a folder called firstinitial_lastname (e.g., V:\...HA1008 MHI\Optical\MOL\OTHER\J_SMITH). File names of images should not include spaces or special characters, including parentheses. Divers should follow instructions in Appendix A2.1 and consult the data manager on their cruise to ensure that photos are correctly catalogued.

Data Entry and Quality Control Measures

Once data collection is complete and all divers are aboard the ship, all data sheets should be rinsed with fresh water and dried in preparation for data entry into the benthic Microsoft Access database stored on the ship's data server. Initial data entry and quality control is the responsibility of the diver who collected the data. Quality control should include error checking the entered data against the data sheet once data for all sites surveyed that day have been entered. These initial quality control measures should be completed by the end of each respective leg of a cruise, but ideally by the end of each day. If errors are found, the database should be corrected to reflect the data on the datasheet.

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Appendices

Appendix 1: Canon Powershot S110 setting

Before each dive day, verify/set these camera settings:

1) Set to “P” (Program)
2) Set ISO to AUTO: Press ”FUNC SET” (functions will show on the left side of screen) > select “ISO” icon > Select AUTO
3) Set image quality to “L”: Press ”FUNC SET” > select “Compression Resolution” icon > select “L”
4) Time settings = UTC: Press “MENU” > select camera settings > scroll down to “Date/Time…”
5) Set it to NO FLASH

During each dive, verify/set these camera settings:

1) White balance:
    a. Set camera to “P” (program)
    b. Press ”FUNC SET”
    c. Highlight “White Balance” icon
    d. Aim the camera to a white object and press “RING FUNC” once.
2) If taking photos in darker/deeper sites or “camera shake warning” shows up on bottom left corner of the screen, adjust ISO setting.
    a. Press “FUNC SET”
    b. Highlight ISO icon
    c. Adjust ISO to 400 or above (Warning: higher ISO results in grainy image. Try not go above 1000)
    d. Press “FUNC SET”

After each dive day, see instructions for ‘Camera Downloads and Managing Optical Data’.

Appendix 2: Camera downloads and managing optical data

If you took any photos at sites, follow this procedure upon your return on each dive day:
CAMERA DOWNLOADING

The photos in the **CameraDownload** folder are our only assurance that any reconstruction will be successful and that a backup exists in case of a problem with the photos in the months and years after the cruise. Be sure to place all original photos here.

1. Create a new directory in:

T:\Cruise	
CruiseData	
[Cruise Directory]	(e.g. SS1601_AmSamoa)
CameraDownload	
ISLANDCODE	(e.g. PAL for Palmyra Atoll)
REA	
BENTHIC	
CameraID	(Currently your First Initial and Lastname, e.g. DSwanson)
MM-DD-YYYY	

2. Do not make any corrections to the original photos. This folder needs to remain intact. DO NOT REMOVE ANY PHOTOS FROM THIS FOLDER! Instead copy and paste photos from this folder to the appropriate Optical folder (see below).

3. Check to ensure <u>all photos</u> have been correctly downloaded from the camera before erasing the camera's memory card.

<u>Photo Quad Photos</u>

1. Check to see if the site folder already exists in

T:\Cruise	
CruiseData	
[Cruise Directory]	(e.g. SS1601_AmSamoa)
Optical	
ISLANDCODE	(e.g. PAL for Palmyra Atoll)
REA	
BENTHIC	
SITE-ID	(e.g. PAL-195, in Caps)

2. If a folder has not yet been created for the site, copy and paste the "SITE-ID" folder into the BENTHIC folder and rename it for the site. Please name the site EXACTLY as shown, no spaces, no underline, just ISLANDCODE (all in Caps), a dash, and a three digit number.

3. The following directories should exist under the [SITE-ID] directory:

PHOTO_QUADS (in Capital letters, exactly as shown)
A (and B) (Capitalized, either A or B)

Copy photos from the newly created CameraDownload folder into the appropriate folders (A = transect 1, B = transect 2); if you took additional benthic photos make sure to delete any extras **(there should be exactly 15 photos in each folder).**

SITE_PHOTOS
Download site photos into the SITE_PHOTOS folder. It's okay to have more than four site photos.

If you have other noteworthy Misc. Photos at the site, create a new folder (directory) using your First Initial and Lastname in:

FI_LASTNAME and put a copy of the photos in this folder

<u>Data Entry</u>
1. For each site where you took Photo Quad images, check the ☑ **TRANSECT_PHOTOS_YN** box in the Coral Data Entry Site sub-screen for that site.

2. For each transect where you took Photo Quad images, but no survey was completed, create a survey entry and uncheck the ☐**SURVEY_DONE_YN** box in the Coral Data Entry Transect sub-screen for that transect.

What do I do if?

Issue	Resolution
You have less than 15 photos for a PHOTO_QUAD Transect…	Add a note to this effect in the notes column on the Benthic Survey Data Sheet (?) or Dive and Navigation Data sheet (?) just before you enter your transect observations
You have too many photos for a PHOTO_QUAD transect…	Ensure all photos are actually photo quad images (occasionally slate images are erroneously included). If all are legitimate images, delete images until only 15 remain
You put a photo quad image in the SITE_PHOTOS folder…	Delete the image from the SITE_PHOTOS folder as duplicate images will be detected and create an error when processed
You notice that you've copied the same photos to two different sites…	Look back in the CameraDownload folder and recopy both folders to the correct directories.
A Survey was done on a transect, but Photo_Quads were not taken	Uncheck the ☐ **TRANSECT_PHOTOS_YN** box in the Coral Data Entry Site sub-screen for that transect and corresponding paper datasheets?

Purpose of Downloading Photos:

- Once the files have been copied to the server, a script is run on them to rename the photos to reflect the cruise and site they were taken so that they can be analyzed for various reasons. The script keys it's renaming off of the folder structure, which it interprets strictly (using the naming conventions outlined in this document). It also expects 15 photos in the PHOTO_QUADS directory and specific flags to be set in the Data Entry Database. Any deviation from the above listed procedure will produce an error that will need to be corrected (either the folder names need to be corrected, the number of files needs to be adjusted, or the Data Entry database needs to be corrected). All errors must be corrected before the cruises photos can be released for analysis.

- Following these instructions with precision is important and will save you, your Team Lead, the Data Manager, and likely several other individuals up the processing chain a good bit of time if they have to reconstruct and reformat what you have done. At each point in the process, the potential exists to render the photos you took unusable simply because they were not put in the right place or were given the wrong name.

Appendix 3. Data entry QC checklist

After benthic REA data has been entered into the ESD Data Entry Application database, check the adult (a) and juvenile (b) data for the following:

Adults

1) Correct date? Site? Transect? Segment? Please double check your data entry for the correct transects and segments. This is one of the most common errors. If someone helps you complete the survey of a segment, ALL of the data from the segment should be entered under one diver and NOT separately by both divers.

2) Check segment length and width. (Did you survey the whole segment?)

3) **Presence check boxes?** Verify that the boxes are checked for the genera or groups found in the segment.

4) **Scroll down your list of entries for the segment. Do you have the same number of colonies as on your data sheet?**

5) Did you enter a value for recent dead %? If so, there **has** to be a cause identified – BOTH Recent dead general and recent dead specific. (e.g. 5 % recent dead, recent dead general = DZGN, Recent dead specific= WSY)

6) Did you enter a category for condition? If so, there has to be an extent value entered (% of colony affected). Do you need a severity (BLE, BLP, SGA, PTR)?

7) Do you have any entries with maximum diameter (L) less than 5 cm? If so, do you have the condition recorded as damage – broken, toppled etc.? Or do you have a note in the comments that indicates a fragment?

Juveniles

1) Correct date? Site? Transect? Segment? (Transect 1 = transect 3; Transect 2 = transect 4). Please double check your data entry for the correct transects and segments. This is one of the most common errors.

2) Check segment length and width. (Did you survey the whole segment?)

3) Is L greater than W for all entries? Maximum diameter (L in the data entry program) should be the largest measurement recorded and entered.

4) Are all entries for L less than 5 cm?

5) **Scroll down your list of entries for the segment. Do you have the same number of colonies as on your data sheet?**

Appendix 4. Benthic survey training worksheet

Rapid Ecological Assessment (REA) Benthic Survey Training Worksheet
Name:
Date:

1. How do you distinguish juvenile colony from an adult colony? Or an asexual fragment?

2. What are the three things that you must write on each of your data sheets?

3. Give a few examples or list the type of features that you would use to characterize a site.

4. List the segment dimensions and locations on each transect used for surveying adult coral colonies.

5. List the segment dimensions and locations on each transect used for surveying juvenile coral colonies.

6. How do you distinguish old dead from recent dead?

7. Is sedimentation a condition or a cause of recent mortality?

8. How do you distinguish recent dead caused by gastropod predation from recent dead caused by Acute tissue loss/ White syndrome (disease)?

9. If a coral colony is fragment and there is no discernable recent dead partial mortality, how would you record the relevant information on your datasheet?

10. If you secure the end of transect 1 to a dead coral branch but you have to use part of the actual tape so that segment 0 actually starts at 0.2m, what are the dimensions of segment 0 (or what is the location of segment 0 on the transect tape)?